

## **Performance demands in the Endurance Rider**

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*Published in:*  
Comparative Exercise Physiology

*Publication date:*  
2021

*This document version is the:*  
Peer reviewed version

*The final published version is available direct from the publisher website at:*  
[10.3920/cep200033](https://doi.org/10.3920/cep200033)

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*Citation for published version (APA):*  
Williams, J., Douglas, J., Davies, E., Bloom, F., & Castejon, C. (2021). Performance demands in the Endurance Rider. *Comparative Exercise Physiology*, 17(3), 199-217. <https://doi.org/10.3920/cep200033>

1 **Performance demands in the Endurance Rider**

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10  
11 **Abstract**

12  
13 Endurance is one of the fastest growing equestrian disciplines worldwide. Races are long  
14 distance competitions (40-160km), organized into loops, over variable terrain usually  
15 within one day. Horse and rider combinations in endurance races have to complete the  
16 course in good condition whilst also aiming to win. Horse welfare is paramount within  
17 the sport and horses are required to ‘pass’ a veterinary check prior to racing, after each  
18 loop of the course and at the end of the race. Despite the health, fitness and welfare of  
19 both athletes within the horse-rider dyad being essential to achieve success, few  
20 equivalent measures assessing the wellbeing of the endurance rider are implemented. This  
21 review considers evidence from ultra-endurance sports and rider performance in other  
22 equestrian disciplines, to consider physiological and psychological strategies the  
23 endurance rider could use to enhance their competition performance. Successful  
24 endurance riding requires an effective partnership to be established between horse and  
25 rider. Within this partnership, adequate rider health and fitness are key to optimal  
26 decision-making to manage the horse effectively during training and competition, but just  
27 as importantly riders should manage themselves as an athlete. Targeted management for  
28 superior rider performance can underpin more effective decision-making promoting  
29 ethical equitation practices and optimizing competition performance. Therefore the  
30 responsible and competitive endurance rider needs to consider how they prepare  
31 themselves adequately for participation in the sport. This should include engaging in  
32 appropriate physiological training for fitness and musculoskeletal strength and  
33 conditioning. Alongside planning nutritional strategies to support rider performance in  
34 training and within the pre-, peri- and post-competition periods to promote superior  
35 physical and cognitive performance, and prevent injury. By applying an evidence  
36 informed approach to self-management, the endurance athlete will support the horse and  
37 rider partnership to achieve to their optimal capacity, whilst maximizing both parties  
38 physical and psychological wellbeing.

39  
40 **Keywords:**

41  
42 Endurance racing; equestrian sport; performance analysis; ultra-endurance; endurance  
43 horse

## 44 Introduction

45

46 Endurance riding is popular worldwide. The sport is governed by the Fédération Équestre  
47 Internationalé (FEI) and is reported to be one of the fastest growing equestrian disciplines  
48 (Bennett and Parkin, 2018; Marlin and Williams, 2018a), with a 68% increase in FEI  
49 registered endurance riders since 2007 (FEI Endurance Report, 2017). Research within  
50 endurance has predominately focused on determining factors which impact endurance  
51 horse health, management and welfare; however to be successful, the wellbeing of both  
52 partners in the horse-rider dyad should be understood. At elite level in any sport the  
53 difference between winning and losing can be attributed to differences in the  
54 physiological or psychological status of the athletes participating in it, unforced errors  
55 from participants, efficacy of training regimens or variance within associated equipment  
56 (Williams, 2013; Woodman and Hardy, 2003; Williams and Ericsson, 2005). One method  
57 to prevent failure and maximize success is to integrate performance analysis into the  
58 review of training and competition practices (Hughes and Bartlett, 2002). Performance  
59 analysis is the systematic observation and analysis of factors identified to enhance athlete  
60 and / or team performance in the context of a specific sport, with the aim to improve  
61 athlete decision-making, in both training and competition, to facilitate increased  
62 competitive success (McGarry, 2009; Williams, 2013). Within equestrian sport, it is  
63 critical for success that any performance analysis techniques applied consider the horse,  
64 the rider, and the horse and rider partnership as separate but interconnected entities  
65 (Williams 2013, Williams and Tabor, 2017). Therefore, the aim of this review is to  
66 evaluate the physiological, nutritional and psychological performance demands on the  
67 endurance rider as an athlete. Evidence from ultra-endurance sports and rider  
68 performance in other equestrian disciplines, will be used to identify potential training and  
69 competition strategies, which could improve individual performance, and by association  
70 enhance the welfare and competitive success of their equine partner.

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73 *What is equestrian endurance racing?*

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75 Endurance is a long-distance competition for horse and rider combinations against the  
76 clock, usually within one day. Competitions, colloquially known as races, test the fitness  
77 and endurance of the horse, and challenge the rider to effectively manage their horse's  
78 pacing strategy across variable terrain, with the aim of the horse completing in good  
79 condition within an optimal time (graded races) or within a traditional race format (FEI,  
80 2020a). Globally, race distances vary between 40km to 160km, with most beginner events  
81 racing over 40 and 60 km, progressing to 80, 120 and 160 km for advanced and  
82 international level competition. At international level, individual and team competitions  
83 are also categorized according to the level of difficulty they represent (Tables 1 and 2);  
84 furthermore to be eligible to compete, horse and rider combinations need to meet strict  
85 qualifying criteria (Table 3). Mandatory out of competition periods (MOOCPs) also apply  
86 to horses at the international level of the sport and can limit participation in races (Table  
87 4); currently no equivalent MOOCP apply for riders.

88

89 In 2017, 930 international races took place, across 52 countries and a total of 7142 riders  
90 and 14949 horses were registered with the FEI (FEI Endurance Report, 2017). Races  
91 occur across the globe in variable climates, therefore the effects of temperature and  
92 humidity can influence both horse and rider performance during races (Marlin and  
93 Williams, 2018a). Managing equine welfare within endurance riding is a key strategic

94 consideration of the FEI; however the majority of research and monitoring during  
 95 competitions focuses on the horse, and how the rider (and their wider team) are  
 96 optimizing equine health and welfare. Races consist of a number of phases or loops; each  
 97 of which may not exceed 40 km and should not be less than 16 km. At the end of each  
 98 loop, there is a compulsory stop (known as the vet gate) for the horse to undergo a  
 99 veterinary inspection, which it must pass to be able to continue racing. However, despite  
 100 the health, fitness and welfare of both athletes within the horse-rider dyad being essential  
 101 to achieve success in endurance riding, there are no equivalent checks in place for the  
 102 rider. The 2020 FEI endurance rulebook states “*participation in competition must be*  
 103 *restricted to fit Horses and Athletes* (defined as the person who rides the horse in  
 104 competition) *of proven competence*” and encourages all those involved in equestrian sport  
 105 to attain the highest levels of education and expertise in the care and management of the  
 106 equine athlete (FEI, 2020a).

107 Horse welfare is the key priority within endurance, reflecting the responsibility and duty  
 108 of care riders, trainers, event organizers and equestrian federations have to protect the  
 109 equine athletes who cannot articulate if their health or welfare is compromised (Williams  
 110 and Tabor, 2017). Riders can participate in endurance as an athlete from the 1<sup>st</sup> of January  
 111 in the year they reach 14 years of age (FEI, 2020a). Male and female riders are treated  
 112 equally as athletes and have a personal and non-delegable responsibility to familiarize  
 113 themselves with the FEI Rules and Regulations. Riders must comply with minimum  
 114 weight requirements when competing in FEI endurance competitions (Table 5); however  
 115 there are no formalized maximum weights for riders in FEI competition and the ratio of  
 116 rider: horse weight is not measured (FEI, 2020a). Event organizers provide a reliable,  
 117 calibrated weighing machine that is used for athlete weight control checks before the start  
 118 (mandatory) and the end (by request of an FEI official) of the competition. Athletes  
 119 should maintain their minimum riding weight throughout the competition regardless of if  
 120 they are riding or leading the horse, and random weight control inspections can occur at  
 121 any time if requested by an FEI official (FEI, 2020). Failing to meet minimum weight  
 122 requirements or to undertake a weight control check, results in the combination being  
 123 disqualified (FEI, 2020a). Riders are also required to concur with anti-doping regulations  
 124 and to declare if they are taking any medication that may enhance performance (FEI,  
 125 2020a). During racing, the ground jury are also authorized to stop a rider if they believe  
 126 they are unfit to continue to race, but there are no compulsory rider health or welfare  
 127 checks that take place after each loop or at the end of the race (FEI, 2020a).

128  
 129 Table 1: Fédération Équestre Internationalé (FEI) categories of starred level endurance  
 130 rides (FEI 2020a); Concours de Raid d’Endurance International (CEI); Concours de Raid  
 131 d’Endurance International Officiel (CEIO).  
 132

Star levels	CEIs, CEIOs and Championships are also usually divided into three star levels (with 3* being the highest level): 1*: Competitions between 100-119 km in one day; minimum of three loops, 2*: Competitions between 120-139 km in one day, or between 7089 km per day over two days; minimum of four loops, 3*: Competitions between 140-160 km in one day, or 90-100 km per day over two days, or 70-80 km per day over three days or more; minimum of five loops, 3* Championship 160km in one day, minimum of six loops.
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134 Table 2. Fédération Équestre Internationalé (FEI) categories of endurance rides in  
 135 accordance with the FEI 2020 Endurance Rules (effective from July 2020) (FEI,  
 136 2020a). The rulebook is available at: <https://inside.fei.org/fei/disc/endurance/rules>

Competition Level	Key criteria for FEI international competitions
Concours de Raid d'Endurance International (CEI)	<p>To participate combinations require official individual classification</p> <p>No official team classification criteria in place</p> <p>The organizing committee can permit athletes to compete in a team of 3 to 5, not necessarily of the same nationality</p>
Concours de Raid d'Endurance International Officiel (CEIO)	<p>To participate combinations require official individual classification and an official team classification for team competition</p> <p>Each nation may enter only one team in the team competition</p> <p>A minimum of 3 teams are necessary for a team competition to be considered an official team competition</p> <p>Each team must have a minimum of three combinations and a maximum of five combinations</p>
Championships (including test events for Championships) and Games	<p>To participate combinations must have an official individual classification and an official team classification for team competition (except for Young Horse Championships)</p> <p>Each nation may enter only one team in the team competition</p> <p>A minimum of 3 teams are necessary for a team competition to be considered an official team competition</p> <p>Each team consists of a minimum of three combinations and a maximum of five combinations</p> <p>1* Championships must be a minimum of 100 km and a maximum of 119km in length, in one day</p> <p>2* Young Horse Championships must be a minimum of 120 km and a maximum of 130 km, in one day</p> <p>2* Junior and Young Rider Championships must be a minimum of 120 km and maximum of 130 km, in one day</p> <p>2* Senior Championships must be a minimum of 120 km and maximum of 139 km, in one day</p> <p>3* Senior Championships must be 160 km, in one day</p> <p>Championships at the Senior or Junior/Young Rider level may be organized on a regional, continental or world level, or as games</p>

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 138  
 139 Table 3: Factors that determine eligibility to compete in FEI endurance races (FEI, 2020)  
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Qualification criteria to determine horse and rider eligibility to compete
Once an athlete or horse complete an event at the CEI level qualification they are permitted to compete at that level.
CEI star ratings are valid for athletes (riders) for 5 years and for horses for 2 years.
If either horse or rider fail to complete an event at the chosen level, then they will automatically drop down one level of qualification and must complete a competition at the lower level to regain their qualification status to be eligible to compete at the higher level which they had previously failed to

complete e.g. if a horse and rider combination did not complete a 2 star race they would need to complete a 1 star race before being able to enter another 2 star race.

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Table 4: Criteria for mandatory out of competition periods (MOOCPs) applied to horses participating in international endurance competitions

<b>Mandatory out of competition periods (MOOCP)</b>
<p>MOOCPs apply to horses and are mandatory:</p> <ul style="list-style-type: none"> <li>a) after competing in a national event or FEI event,</li> <li>b) which exceed an average of &gt;20km/hr over the loops of a race,</li> <li>c) record multiple metabolic eliminations, and,</li> <li>d) incur a serious musculoskeletal or metabolic injury within a rolling year period.</li> </ul> <p>NOTE: MOOCPs do not exist for riders</p>

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Rider safety is a key consideration of event organizing committees and officials are allowed to provide assistance if the athlete falls off or is separated from their horse, although this does not equate to mandatory retirement from the race or require a subsequent mandatory out of competition period to be completed. Riders are also allowed to use mobile phones and GPS devices during the race. Athlete support during the events is provided at designated areas on the course known as crew points. At these points, the rider's support team (or crew) can provide the rider with water and food, although anecdotally often riders will wait until the veterinary hold areas until eating. Crew points are required to be at least 5km apart. The FEI provide more general human athlete support via their 'Athlete Toolkit', which is applicable to riders across all FEI equestrian disciplines. The toolkit provides advice on clean sport and includes recommendations on how to stay healthy when competing, guidance on recognizing concussion, safe horse handling and recommended PPE, as well as covering sports psychology and mental training techniques (FEI, 2020b). However no specific guidance for equestrian athletes on how to manage their fitness, or dietary and hydration management are currently included in the toolkit.

Table 5: FEI minimum athlete (rider) weight requirements for endurance (FEI, 2020a)

<b>Event</b>	<b>Minimum weight</b>
Young Rider / Junior competitions and championships	60 kg unless competing in senior competitions when senior weights apply
Senior: Concours de Raid d'Endurance International (CEI) 1* and 2*	70 kg
Senior: Concours de Raid d'Endurance International (CEI) 3*	75 kg
Senior: Concours de Raid d'Endurance International (CEIO) and Championships	75 kg

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169 *Performance demands on the endurance rider*

170 To participate effectively in an endurance competition, both horses and athletes (riders)  
171 must be physically fit. To date research in endurance riding has largely focused on  
172 determining the performance demands on the equine athlete (for example: Fraipont et al.,  
173 2012; Castejón-Riber, 2014), with limited evaluation of the performance demands  
174 experienced by the endurance rider during competition, or identification of key  
175 performance characteristics in the successful endurance rider. Riding strategies have been  
176 investigated: for example Viry et al. (2013; 2015) analyzed gait selection across horse  
177 and rider dyads within competition, and Marlin and Williams (2018a, b) examined the  
178 relationship between rider self-selected pacing strategies on completion and elimination  
179 rates in international endurance races. These studies indicate how rider actions and  
180 decision-making can influence equine welfare and performance, and highlight the  
181 importance within equestrian sport of considering the directorial impact of the human  
182 athlete within the horse-rider dyad (Williams and Tabor, 2017).

183 The performance demands of endurance riding are multifaceted and will differ according  
184 to horse, race and environmental factors (Figure 1). The successful endurance rider  
185 requires sufficient physiological and psychological fitness to remain in balance, prevent  
186 fatigue and retain the ability to assimilate relevant visual and physical information to  
187 inform effective decision-making, and execute appropriate riding strategies to optimize  
188 the performance of their equine partner (Williams, 2013). However to date, the lack of  
189 evidence-based research into rider performance in endurance is self-limiting and has  
190 wider impacts on the development of endurance riding as a sport. As a result, the demands  
191 of endurance riding are currently speculative and whilst the application of evidence from  
192 comparative ultra-endurance disciplines can be used to postulate and underpin effective  
193 training and competition strategies, discipline specific studies are required to progress the  
194 development of the rider as an athlete in the endurance.

#### 195 *Physiological Demand of Endurance Riding*

196 To date, attention regarding the physiological response of the rider in endurance riding  
197 mirrors the limited focus on the rider across all equestrian sports and the actual  
198 physiologic demands of endurance riding are not yet documented. There has been  
199 emerging research that investigates responses to horse riding including measures such as  
200 heart rate, oxygen uptake, blood lactate across different equine gaits within variable riding  
201 positions in both simulated: horse simulator and live horse within training, and live ridden  
202 competitive situations (Westerling et al. 1983; Trowbridge et al. 1995; Devienne and  
203 Guzenec 2000; Perciavalle et al. 2014; Beale et al. 2015; Cullen et al. 2015; Sainas et  
204 al. 2016; Douglas et al. 2017) which can be applied to the context of endurance riding.

205 Endurance riding is a broad discipline with variable race distances up to 160km and thus  
206 the physiological responses are likely to be affected by the duration of the event and the  
207 riding positions adopted by the rider. In endurance riding, the rider aims to minimize the  
208 metabolic cost to themselves and the horse by managing gait and speed to optimize the  
209 horse's functional health status (Viry et al. 2015), although this has not been studied in  
210 riders in a physiological capacity to date. Endurance riders will adopt different riding  
211 positions throughout a race, shifting between 2 point and 3 point seat (Figure 2a and 2b,  
212 respectively) in trot and canter, but often spending more time in 2 point positions (Viry  
213 et al., 2013). Strategies riders select to accommodate the horse's motion at trot (e.g. rising,  
214 2 point seat or 3 point seat 'sitting' to the gait), can influence energy expenditure, with  
215 riders shown to expend more energy in rising trot compared to sitting or 2 point seat upon  
216 a riding simulator (De Cocq et al., 2013). In the two point seat the rider's weight is borne

217 by the stirrups without any contact of the rider's seat with the saddle; this results in the  
218 riders body experiencing reduced amplitude vertical and longitudinal displacements  
219 (Clayton and Hobbs, 2017). Canter is often easier to sit to for the rider due to the smaller  
220 longitudinal accelerations and decelerations within this gait, which makes it easier for the  
221 rider to coordinate their movements with the horse (Terada, 2000; Clayton and Hobbs,  
222 2017). Though research is sparse, early work indicates that rider positions requiring more  
223 weight bearing from the rider, such as a 2-point seat, increases physiological demand due  
224 to degree of muscular activity required to coordinate movements of the rider's legs, arms  
225 and trunk (Clayton and Hobbs, 2017). To date research has documented that heart rate  
226 and blood lactate responses of the rider increase with the horses gait and markedly  
227 increase in canter and where jumping efforts are concerned (Westerling et al. 1983;  
228 Trowbridge et al. 1995; Devienne and Guzenec 2000; Cullen et al. 2015; Douglas et al.  
229 2017). The increased physiological demand associated with changes in rider positions  
230 was reported to be matched by increased calorie consumption and thus metabolic cost  
231 during activities (Sung et al. 2015). Equestrian disciplines that require a rapid change in  
232 pace and direction such as cutting and reining report increased energy expenditure  
233 (metabolic equivalents of task, MET) during reining and cutting, compared to walk, trot  
234 and canter protocols. The authors' state that MET was also higher during trot and canter  
235 when compared to walking only tasks (Sung et al. 2015).

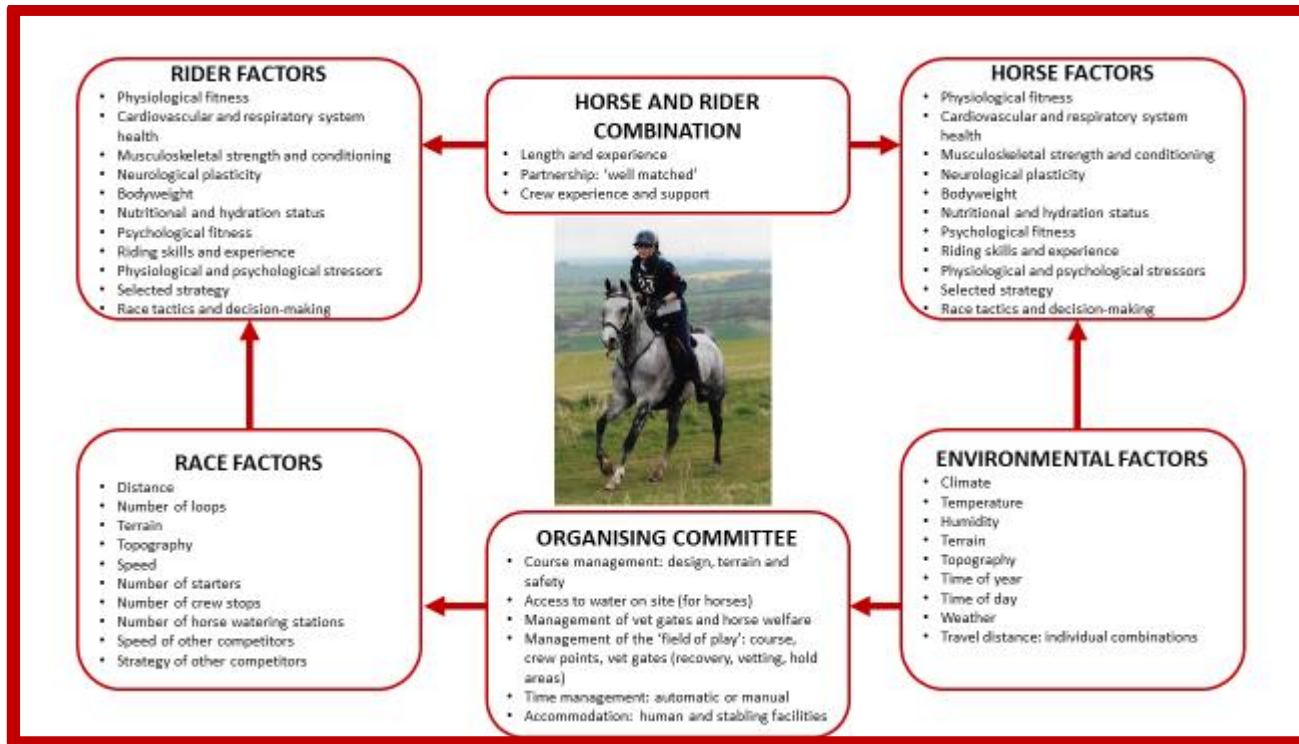
236 Although metabolically costly to the rider (Westerling 1983; Devienne and Guzenec  
237 2000; Trowbridge et al. 1995; Roberts et al. 2009; Perciavalle et al. 2014; Beale et al.  
238 2015; Sainas et al. 2016), the 2-point seat benefits equine welfare and performance by  
239 reducing loading on the horses back, compared to the 3 point seat where the rider spends  
240 more time in contact with the saddle and thus if the rider is conditioned appropriately can  
241 be an effective dyad strategy to improve performance and welfare.

242 A third riding style 'the desert seat' is becoming increasingly popular in endurance riders  
243 (Viry et al., 2014); anecdotally this position is reported to be more comfortable for male  
244 riders. The desert seat is essentially an adapted 3 point seat; however the rider uses a more  
245 minimalist and lightweight saddle combined with longer stirrup length and sits with the  
246 feet placed more forward than in standard endurance equitation, and the upper body set  
247 farther back, which is thought to facilitate a high degree of mobility in the pelvis (Lesté-  
248 Laserra, 2017). Clayton and Hobbs (2017) suggest elite riders can control their  
249 movements to increase synchronicity with the horse's movements, improving their  
250 consistency. Initial biomechanical evaluation of the desert seat within a 130km race  
251 reports improved quality of horse-rider coupling in seated canter, with vertical horse and  
252 rider displacements more in phase resulting in a reduced physiological load to the rider  
253 compared to the traditional 3-point seat (Viry et al., 2014). The study also found that  
254 riders when using the desert seat and tack, spent approximately four times longer during  
255 racing in sitting canter (>80%), horses' average speed increased by 5.6%, and horses'  
256 galloped for 30% longer than when using traditional riding approaches (Lesté-Laserra,  
257 2017; Viry et al., 2014). While on the surface these results suggest using a desert style  
258 seat is more efficient for the rider, further studies across greater numbers are needed to  
259 confirm this. The impact on equine welfare should also be considered; Marlin et al.  
260 (2018a, b) and Bennet and Parkin (2018) have shown increased speeds in racing are  
261 associated with a higher risk of elimination and injury in endurance races. Nagy et al.  
262 (2017) reported thoracolumbar pain to be the second most common veterinary problem  
263 experienced by endurance horses and also found higher average speeds in canter were  
264 associated with an increased risk of lameness. Despite enhancing coupling between the



265 horse and rider, the trend for spending more time in a seated gallop observed in riders  
266 adopting the desert seat could potentiate these issues and further work exploring the  
267 impact of using this riding style on both endurance rider and horse performance and  
268 welfare are warranted.

FINAL DRAFT



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270

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Figure 1: Factors that contribute to successful completion of endurance competitions (adapted from FEI, 2020a; Williams, 2013; Marlin and Williams, 2018a, b, Bennett and Parkin, 2018)

272 Cumulative research studies agree that physiological markers of exercise intensity  
273 increase as rider positions and horse gaits progress from walk, to 2-point and jumping  
274 positions. There is however early work that reports that the physiological responses to  
275 horse riding are more multifactorial and require further understanding to further  
276 understand the demands of equestrian sport on the rider. Douglas et al. (2017) reported  
277 that unlike heart rate and blood lactate, oxygen uptake data do not rise at the same rate as  
278 heart rate during horse riding activities, and in general are not representative for what is  
279 documented during dynamic exercise. In dynamic exercise, a rise in heart rate is linear to  
280 oxygen consumption and a more marked blood lactate concentration is apparent.  
281 Collective data in physiological demands of horse riding are in agreement with this  
282 finding (Westerling 1983; Devienne and Guzenec 2000; Trowbridge et al. 1995; Roberts  
283 et al. 2009; Perciavalle et al. 2014; Beale et al. 2015; Sainas et al. 2016). Douglas et al.  
284 (2017) have proposed that a dissociation between heart rate and oxygen uptake are the  
285 result of the high requirements for isometric muscle activity which stimulate a  
286 disassociation between physiological parameters as a response to increases in rider blood  
287 pressure. Therefore ultimately horse riding in a 2 point canter may elicit a high heart rate  
288 in riders, but this high heart rate may not be truly reflective of the actual physiological  
289 load or energy requirements of riding itself. A further understanding the physiological  
290 responses of horse riding and the discipline specific demands will assist practitioners to  
291 condition the riders appropriately to offset fatigue and be in a position to adapt position  
292 to best support the competitive equestrian dyad.

293 Ultimately, when considering the physiological demands of endurance riding on the rider,  
294 it is sensible to consider the distance and thus duration of the race, and how much time  
295 the rider spends in each riding position. The proportional use of each riding technique  
296 used in endurance riding is explained in an exploratory capacity by Viry et al. (2015).  
297 This research group highlighted in international equine endurance races of 130km, the  
298 majority of race time was spent in two point canter (34%) and rising trot (33%) followed  
299 by sitting canter (3 point seat; 21%) and 2 point trot (12%). Detailed time motion analysis  
300 matched to the physiological response of endurance racing to riding demands is necessary  
301 to further evaluate the demands placed on these (human) athletes, however, the initial  
302 data suggests that mixing predominantly a two point canter with rising trot is  
303 metabolically advantageous to both the horse and rider. The two point canter is  
304 metabolically costly to the rider, and based on current data would elevate heart rate  
305 substantially as a result of long duration isometric contractions of the thigh (Douglas et  
306 al. 2017), however periodic phases of rising trot would allow for replenishment of energy  
307 utilization and fatigue substrate dissipation facilitated by dynamic motion.

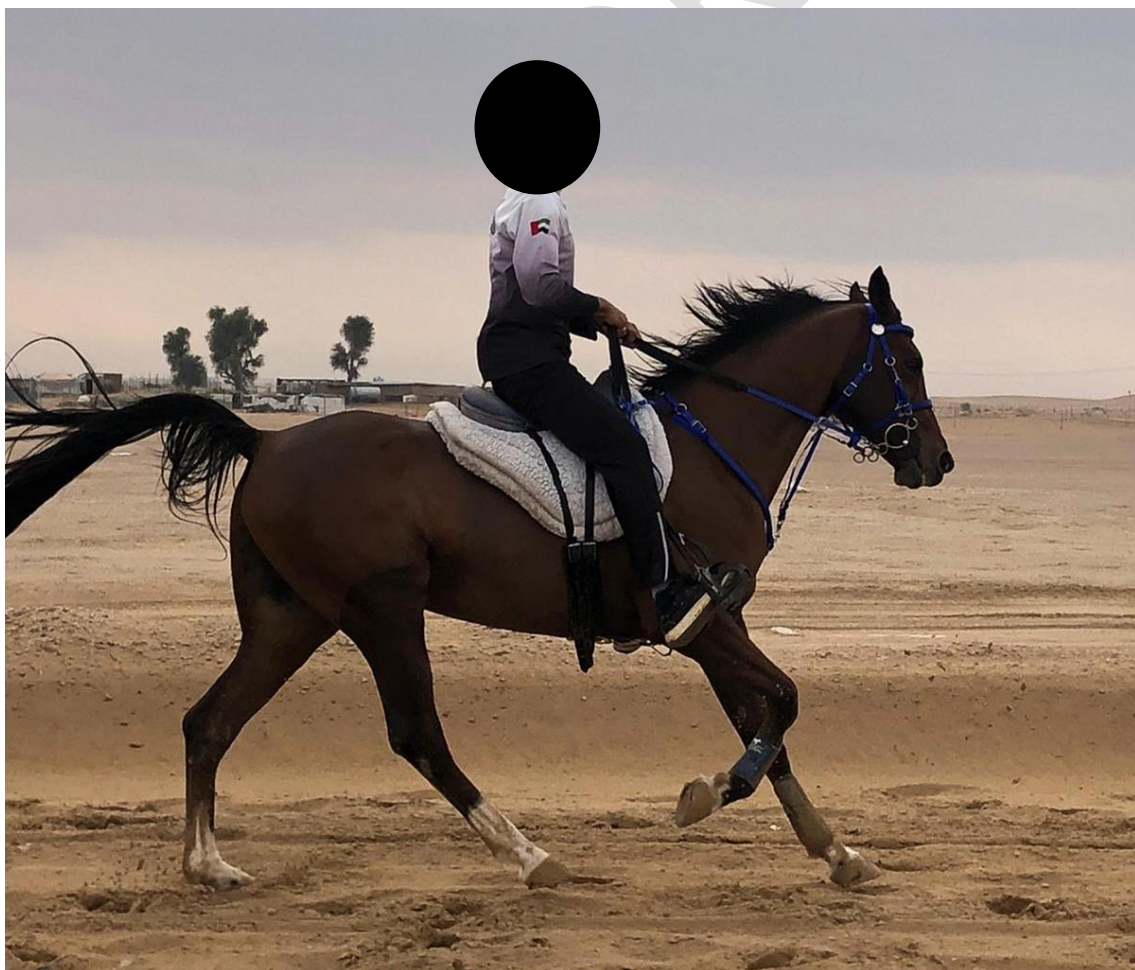
308 Though not well documented, there are supportive data that physiological demand differs  
309 between skill level of the athlete; for example, the senior league of Australian Football is  
310 played at a faster rate than junior league requiring superior aerobic and anaerobic  
311 capacity, speed, agility, strength and power (Burgess et al., 2012 Gray and Jenkins, 2010).  
312 Similarly differences in physiological and kinematic performance have also been reported  
313 linked to individual skill level in swimming (Pyne and Sharp, 2014; Seifert et al. 2008)  
314 and sailing (Friesenbichler et al., 2018). Sung et al. (2015) reported exercise intensity and  
315 calorific consumption to be non-significantly elevated in amateur riders compared to  
316 elites. The authors conclude that elite athletes consumed less calories for a given task and  
317 was implied that this was due to elite athletes being more rhythmically harmonized with  
318 their horse which reduced unnecessary calorie consumption, and that markers of intensity  
319 are affected by skillful control of elites. Though exciting as a discussion point and a

320 potential direction of future research, these data should be interpreted with caution as  
321 many markers of physiological intensity were non-significantly elevated and the  
322 discussion was not supported with biomechanical investigation. It does highlight the  
323 potential for future rider performance research enquiry to consider the synchrony of the  
324 equestrian dyad and its relationship to physiological demand.



325

326 Figure 2: A) 3 point seat in canter; B) 2 point seat in canter (photos FB)



327

328 Figure 3: Example of 'desert seat' position (reproduced with permission)

329 The vacillating nature of equestrian sport and the complexities of each course and each  
330 venue being different means that the physiological demands of riding are likely to be  
331 dependent on course specifics, and as such ideal conditions are sporadic. As a sport where  
332 riders are likely training multiple horses ideally riders need to be physically conditioned  
333 to tolerate a high riding training load in addition to the demands of the actual competition,  
334 to perform optimally in competition and avoid injury.

### 335 *Physical demands*

336 There is a paucity of research concerning the physiological demands of endurance riding  
337 in general on which riders, trainers and coaches can base physical preparation strategies  
338 for endurance riders. Studies have shown that riding activities alone are insufficient to  
339 prepare equestrian athletes for the physical and physiological demands of riding and  
340 additional aerobic and strength and conditioning training regimes are required to prepare  
341 athletes for the demands of riding (Hyttinen et al., 2019; Kiely et al., 2019; Meyers, 2006).  
342 It would appear based on data concerning horse riders in general that endurance riding  
343 may evoke considerable cardiac strain; in a study examining physiological responses of  
344 horse riding, heart rate was reported as 160 beats.min<sup>-1</sup> during Dressage competitions,  
345 168 beats.min<sup>-1</sup> for Show Jumping events and 177 beats.min<sup>-1</sup> during the Cross Country  
346 phase (Douglas et al. 2017). Ultimately, heart rate responses of the rider increase with the  
347 horse's gait and markedly increase in rider positions that require a 2-point seat  
348 (Westerling et al. 1983; Trowbridge et al. 1995; Devienne and Guzenec 2000; Cullen et  
349 al. 2015).

350 Blood lactate concentration has previously been reported in Show Jumping (4-6.3  
351 mmol.l<sup>-1</sup>), National Hunt racing (7 mmol.l<sup>-1</sup> ) and simulated One Day Event riding (9.5  
352 mmol.l<sup>-1</sup> ), and collective research to date indicates that blood lactate concentration is  
353 greater where 2-point positions are required. Levels of blood lactate accumulation  
354 reported are above threshold levels indicating that riders adopting these positions should  
355 be conditioned to increase lactate threshold to improve performance and decrease onset  
356 of fatigue. A study by Perciavalle et al. (2014) concluded that although the concentrations  
357 of blood lactate were moderate in riders post a show jumping round, they were great  
358 enough to worsen reaction time in riders and provides further justification for endurance  
359 riders to condition themselves to off-set the early onset of blood lactate concentration.

360 Long durations spent in 2-point gaits during endurance riding would require an ability to  
361 tolerate sustained high heart rates and periods of peripheral fatigue of the thigh  
362 musculature and may be limiting factors for performance if not addressed with  
363 appropriate physical training. Further research to understand the physiological demands  
364 of this sport are necessary to enhance performance of the horse and rider dyad, and to  
365 facilitate evidence-based and sport-specific physical preparation strategies for riders.

366 Like most sports, endurance riding requires trunk flexion and extension combined with  
367 movement patterns and demands that require the body to move in a coordinated and  
368 reactive manner. As such, total body exercises (squats, deadlifts, presses, rows and pulls)  
369 should form the basis of a rider's training plan. Riders should work muscles over full  
370 ranges of motion to prevent injury in addition to sport specific movements detailed below.  
371 As a sport that requires balancing on another animal, it is considered an unstable sporting  
372 environment, as such, functional exercises that enhance neuromuscular response to an  
373 unstable environment, such as those performed on balance boards and stability boards

374 have been proposed to be key aspects of a riders training programme. It should be noted  
 375 however, that a rider should be symmetrical and functional in their land based training  
 376 before moving to dynamic and unstable training methods.

377 Movement specific exercises should be included in an off-horse training programme, with  
 378 emphasis on time under tension, isometric work and introducing periods of relief that  
 379 mimic the 2-point position. Iso-ballistic exercises (e.g. isometric holds with intermittent  
 380 ballistic movements) and oscillatory isometric exercises (e.g. squats with pulses)  
 381 introduce the rider to movements that will improve the bodies stabilitative mechanics to  
 382 changes in movement patterns observed during positional changes and changes in the  
 383 terrain seen during endurance events.

384 In addition to sports specific training it is important that equestrians consider the  
 385 asymmetric nature of an equestrian lifestyle (Symes and Ellis, 2009; Hobbs et al. 2014)  
 386 and aim to improve functional strength and dynamic posture identifying muscular  
 387 weakness and imbalances throughout the body in attempt to reduce the potential for injury  
 388 occurrence (Lewis and Kennerly, 2017; Lewis et al. 2019). Several studies have reported  
 389 the incidence of injuries in equestrians and 96% of riders have been reported to use pain  
 390 medication to offset chronic pain (Lewis and Kennerly, 2017; Lewis et al. 2019) As such,  
 391 riders should include injury prevention and posture based exercises that focus on  
 392 increasing mobility and stability of the scapular and shoulder girdle, strengthening the  
 393 posterior chain and mobilising the hip flexors to alleviate high occurrence of upper and  
 394 lower back pain in riders (Lewis et al. 2018)

395 The competition season for Endurance varies depending on the country and hemisphere  
 396 horse and rider combinations compete in, with some countries such as the United  
 397 Kingdom, having a defined season predominately focused between March to October,  
 398 and so optimum performance will likely be periodised for key competition dates within  
 399 this period. Many professional endurance riders will compete all year round, moving  
 400 between countries and hemispheres. The variability in a rider's competition schedule is  
 401 therefore extremely varied, making hypothetical training plans complicated, however  
 402 riders should still consider the importance of tailoring their own peak performance to key  
 403 events within their competition schedule. Table 6 details a hypothetical periodised  
 404 training plan for an endurance rider aiming to reach peak riding condition during  
 405 July/August.

406 Table 6: Example periodised plan for Northern hemisphere endurance rider aiming for  
 407 peak fitness during July / August

Month	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC
Mesocycle	Base Fitness		Strength		Specific		Peak Fitness		Specific		Active Recovery	

408 During the base fitness mesocycle, aerobic power and muscular endurance should be the  
 409 focus of development, achieved through total body aerobic exercise modes such as  
 410 running, cycling or rowing. High repetitions of total body movements (squats, deadlift,  
 411 presses, rows and pull variations and progressions) should be included. The strength  
 412 mesocycle focusses on aerobic power of the rider whilst developing strength; the selection  
 413 of exercises should remain similar to the base cycle but progress exercises and variation  
 414 suited to the development of the athlete, with a maximum of 10-12 repetitions. From a  
 415 conditioning perspective, aerobic fitness can be progressed to manipulate the energy

416 systems working above and below aerobic threshold in an interval based training method.  
417 As a sport with an imposed weight limit, the strength and conditioning coach and  
418 endurance athlete should discuss weight making tactics with the riding coach and  
419 nutritionist to ensure employed tactics do not affect physiological or psychological  
420 performance. If planned early enough into the periodised plan, a combined exercise and  
421 nutritional strategy can be adapted to enhance a safe reduction in weight of the rider.

422 The goal of the specific cycle is to introduce and develop movements such as previously  
423 mentioned balance exercises and movements that replicate the demand of the sport. This  
424 phase allows the rider to perfect their stabilitative mechanics to reactions of the horse due  
425 to the varied nature of terrain, equine unpredictability, and rider positional tactics.  
426 Examples may include isometric holds with ballistic movements, squats with pulses to  
427 add concentric/eccentric muscle activity in the working muscle and plank hold variations.

428 This hypothetical plan provides a base, however the strength and conditioning coach  
429 should manipulate the mesocycles to address the athletes specific goals and be flexible to  
430 adapt to environmental, tactical and individual conditions by adaptation of exercise  
431 intensity and volume of land based training to maintain a desired training load.

#### 432 *Nutritional demands of endurance riding*

433 An athlete's nutritional status is crucial for their performance (Thomas et al, 2016) and  
434 while rider training and diet logs are available commercially, there is a paucity of research  
435 evaluating the performance demands of the rider as an athlete. To date studies have focused  
436 on identifying the best nutritional strategies to promote optimal performance in the horses.  
437 The individual rider's aerobic fitness, weight and strength and conditioning as well as race  
438 distance and the riding style adopted during racing will influence the metabolic demands,  
439 and therefore the subsequent nutritional requirements of the endurance rider. Endurance  
440 sports are defined as sports where athletes exercise at submaximal intensity for prolonged  
441 periods of time (Segens, 2012). The endurance athlete requires a combination of muscular  
442 endurance (the ability of a muscle/s to repeatedly develop or maintain force without  
443 fatiguing) and cardiorespiratory endurance (the ability of the cardiovascular and respiratory  
444 systems to deliver blood and oxygen to enable muscle/s to perform continuous exercise) to  
445 be successful (Fink, 2010). Endurance athletes undertake training or competitions which  
446 comprise between 30 minutes and 4 hours, with athletes participating in events that last  
447 longer than this commonly known as ultra-endurance athletes (Williamson, 2016; Fink,  
448 2010). Ultra-endurance sports can also be classified according to distance (Spenceley et al.,  
449 2017), with the literature describing runs longer than the standard marathon of 26.2 miles  
450 (Mueller, 2012); cycling over 100 miles (Linderman et al., 2003), events of duration longer  
451 than 6 hours (Zaryski and Smith, 2005); multiple distance triathlon (Kenechlet et al., 2008)  
452 and multiday races (Lahart et al., 2013) as ultra-endurance sports. Endurance riders will  
453 often train and compete for time periods analogous to those of ultra-endurance athletes in  
454 other disciplines and race distances even at lower levels are longer than those of other  
455 equestrian disciplines. Due to the duration and continuous nature of ultra-endurance sports,  
456 these athletes often attain energy expenditures of 6000 to 8000 kcals/day, therefore it is  
457 essential that nutritional strategies to support athlete performance and health are put in place  
458 to support the demands of these sports (Fink, 2010). Therefore the performance demands  
459 for ultra-endurance athletes will be applied into the endurance riding context to propose  
460 potential strategies that individual endurance riders could personalize to accommodate the  
461 demands of specific climates, competitions and athlete health and fitness status.

462 The nutritional considerations of ultra-endurance athletes focus on ensuring adequate  
463 caloric and nutrient intake during training, combined with adequate energy and fluid  
464 replacement during competition to maintain optimal performance (Applegate, 2010; 1991).  
465 The nutritional demands on the endurance rider may be similar to ultra-endurance athletes,  
466 who train 1-6 hours or longer daily and compete in events up to 24 hours duration  
467 (Williamson, 2016). Usually endurance riding competitions last more than 4 hours in  
468 duration, although at elite level this time will be interspersed by breaks between loops, and  
469 anecdotally endurance riders regularly train for periods longer than this. To the authors'  
470 knowledge, no studies have evaluated the nutritional strategies in endurance riders. Ultra-  
471 endurance athletes often train for several hours a day leading to chronic fatigue, weight loss  
472 and poor performance, therefore the duration, intensity, frequency and type of exercise  
473 undertaken should be considered when formulating individual's nutritional strategies. For  
474 competition, these athletes are encouraged to undertake glycogen super-compensation and  
475 eat a pre-race meal 4 hours before the start, to enhance performance (Applegate, 2010;  
476 1991). The impact of fluid and electrolyte losses during training and competition should  
477 also be considered, and macro and micro nutrient supplementation is often recommended  
478 for these athletes (Applegate, 2010).

479 Adequate energy intake is essential for optimal performance. Professional endurance riders  
480 may train more than one horse every day of the week, some days they may train more than  
481 4 hours, while other amateur endurance riders may ride just 2-3 days per week. To assess  
482 caloric adequacy during training, endurance riders should record and monitor body weight  
483 (after voiding) weekly (at the same time each week) and ensuring they are adequately  
484 hydrated prior to being weighed to prevent fluctuating fluid losses influencing the results  
485 (Casa et al., 2000; Applegate, 1991). The schedule of these athletes may also limit  
486 opportunities for eating, which may be combined with reduced appetites due to heavy and  
487 prolonged training, limiting energy intake or athletes trying to take on board a heavy caloric  
488 load in a short time frame. In ultra-endurance athletes, the caloric cost of training has been  
489 reported as ranging from 180 to 400 kJ or 150 to 400% more energy than their sedentary  
490 peers (Applegate, 1991). Carbohydrate is the preferred fuel source when exercise intensity  
491 is greater than 65% of an athlete's  $VO_{2max}$ , however in ultra-endurance training, exercise  
492 intensity tends to decrease as duration increases, therefore both fat and carbohydrate intake  
493 should be considered to retain a positive nutritional status. Daily carbohydrate requirements  
494 for athletes vary according to level of exercise, from 5–7 g/kg/day (1 h/day of moderate  
495 exercise), 6–10 g/kg/day (1–3 h/day of exercise), to 8–12 g/kg/day ( $\geq$  h/day of exercise)  
496 (Vitale and Getzin, 2019).

497 Recent guidance for ultra-endurance athletes exercising daily for 4 to 5 hours undertaking  
498 moderate to high intensity advocate carbohydrate targets of up to 8–12 g/kg/day of Jager et  
499 al. (2017). The International Society of Sports Nutrition (ISSN) also recommends athletes  
500 should employ an 8–12 g/kg/day high carbohydrate diet to maximize glycogen stores  
501 athletes. For events lasting longer than 90 minutes, such as endurance racing, carbohydrate  
502 loading or glycogen super-compensation in the preceding 36 to 48 hours is considered to  
503 enhance performance by 2 to 3% (Jeukendrup et al., 2005; Jeukendrup, 2004). Recent  
504 studies have found that short-term high-intensity exercise (or even complete physical  
505 inactivity) followed by one day of high (10–12 g/kg/day) carbohydrate intakes can achieve  
506 the same glycogen super-compensation as traditional super-compensation strategies:  
507 carbohydrate depletion followed by high carbohydrate intake strategies. Interestingly, the  
508 former approach maintains glycogen stores (in the absence of exercise depletion) for up to  
509 three days (Jeukendrup et al., 2005; Bussau et al., 2002), providing greater flexibility for  
510 athletes with gastrointestinal (GI) intolerability or GI distress prior to competition. In the



511 final 1–4 hours prior to the event, A further single dose of 1–4 g/kg of carbohydrate is  
512 recommended 1 to 4 hours before the event for a final top-up of liver glycogen stores, as  
513 endurance events commence in the early morning directly after the overnight fast which  
514 depletes liver glycogen (Jager et al., 2017; Vitale and Getzin, 2019). During races over 60  
515 minutes duration, active fueling strategies are recommended to maintain carbohydrate  
516 accessibility typically for events of between 1 to 2.5 hours, 30–60 g/h is commonly  
517 recommended (Jager et al., 2017; Burke et al., 2014) in a 6–8% CHO solution  
518 (concentrations typically found in commercial sports drinks), ideally consumed every 10–  
519 15 minutes (Thomas et al., 2016). Whilst for events lasting longer than 2.5 hours, higher  
520 intakes of 60–70 g/h of carbohydrate, and up to 90 g/h if tolerable have been associated  
521 with improved ultra-endurance athlete performance Jager et al., 2017; Vitale and Getzin,  
522 2019). However, it should be noted that studies evaluating fatigue in ultra-athletes suggest  
523 that glycogen depletion alone does not account for fatigue (Noakes, 2000; Vitale and  
524 Getzin, 2019); therefore other carbohydrate sources such as lactate utilization and  
525 alternative mechanisms, such as increased capability to oxidize fat (Burke et al., 2011), are  
526 postulated to contribute to fatigue, and should be considered when designing nutritional  
527 strategies (Vitale and Getzin, 2019).

528 Fat consumption increases alongside increased carbohydrate intake, and whilst specific fat  
529 supplement strategies are not required, fat stores can provide valuable energy sources.  
530 Ultra-endurance athletes often avoid high-fat foods for fear of weight gain; however high-  
531 fat foods such as peanut butter can help athletes increase their caloric intake, particularly in  
532 individuals who struggle to achieve their daily requirement. Ultra-endurance athletes are  
533 advised to follow public health guidelines to ensure they maintain an adequate fat intake,  
534 and only consider limiting fat intake pre-race during a carbohydrate loading phase or pre-  
535 race if they have GI comfort concerns (Jager et al., 2017; Vitale and Getzin, 2019). While  
536 generally sports nutrition guidelines have advised carbohydrate rich diets for athletes, the  
537 impact of a ketogenic diet on athletic performance has become the subject of much interest  
538 in recent years (McSwiney et al., 2019a). A ketogenic diet is made up of low-carbohydrate  
539 (<20–50 g/d), moderate protein and high-fat (>75–80% energy) intakes, where  
540 monounsaturated and saturated fatty acids sources are prioritized as the main dietary  
541 components (Evans et al., 2016; Phinney and Volek, 2011). This approach is associated  
542 with increased circulating levels of free fatty acids and ketone bodies (acetone, acetoacetate  
543 (AcAc) and beta-hydroxybutyrate ( $\beta$ Hb)) similar to what is observed in a nutritional ketosis  
544 crisis (starvation) (McSwiney et al., 2019a, b). No long term performance enhancing  
545 benefits from adopting a ketogenic diet have been reported in endurance athletes; however  
546 it is important to note that a ketogenic diet did not cause a performance decrement unless  
547 athletes were competing at >70%  $\text{VO}_{2\text{max}}$  (McSwiney et al., 2019b). There are anecdotal  
548 reports of endurance riders adopting a carbohydrate-restricted dietary approach in practice  
549 and recent FEI changes to rider weight rules may facilitate these in male riders. Further  
550 work is needed to fully evaluated the impact of these types of diets on long term rider health  
551 and welfare.

552 Protein is also important and can be used as a fuel source, providing 5 to 15% of energy  
553 expenditure through amino acid oxidation, and a positive nitrogen balance is required to  
554 facilitate tissue repair (Vitale and Getzin, 2019). Therefore ultra-endurance athletes often  
555 have a higher protein intake (2.0 to 2.5g /kg/ day) compared to general athletes (Onywera  
556 et al., 2004). Vitale and Retzin (2019) suggest increasing protein intake on the day  
557 preceding and day of competition may have some performance benefits. They recommend  
558 a competition strategy of protein doses of 0.3 g/kg (or ~20–40 g of protein), every 3–5 h  
559 spread throughout the competition (including a dose immediately before and 0 to 2 hours

560 post-competition) to a total of ~1.2–2.0 g/kg/day, to promote a positive nitrogen balance to  
561 benefit endurance athlete performance and recovery.

562 Increased dietary protein is also advocated to promote muscle hypertrophy, retain muscle  
563 mass and to facilitate tissue repair post exercise (Moore et al., 2014; Philips et al., 2011).  
564 The maintenance of muscle mass is a balance between muscle protein synthesis (MPS) and  
565 muscle protein breakdown (MPB), with the goal of retaining the body in a positive nitrogen  
566 balance (Philips et al., 2011). Prolonged, sustained endurance training results in significant  
567 metabolic demands on the athlete's body including depletion of endogenous fuel stores (e.g.  
568 liver and muscle glycogen), loss of body fluid and electrolytes, hormonal perturbations, and  
569 damage and disruption to skeletal muscle and body proteins (Moore et al., 2014). Recovery  
570 strategies for competitive athletes engaged in endurance-based training typically focus on  
571 3 inter-related approaches: refueling, rehydration, and repair (Moore et al., 2014). Post-  
572 exercise intakes of protein occur at the optimal time to attenuate damage and promote repair  
573 by stimulating MPS (Burd et al., 2009; Philips et al., 2011; Moore et al., 2014). The dose  
574 of protein that appears to maximally stimulate MPS appears to be in the range of 20–25 g /  
575 kg, although this figure may be reduced for lighter athletes, such as endurance riders, below  
576 <85 kg (Philips et al., 2011).

577 The quality of protein ingested is an important factor to consider. Quality is measured by  
578 the protein digestibility corrected amino acid score or PDCAAS; higher quality proteins  
579 record a PDCAAS of 1.0 or close to 1 (Philips et al., 2011). Animal derived protein sources:  
580 milk, eggs and meat have scores are high quality and are artificially truncated at 1.0 despite  
581 the fact that isolated the actual scores of milk proteins, casein, and whey proteins are  
582 reported as ~1.2 (Phillips et al., 2009). Soy is an alternative plant based source of high  
583 quality protein, scoring 1.0 in an isolated format (Philips et al., 2011). Habitual  
584 consumption of dairy products to promote muscle recovery and adaptation has been studied,  
585 and it appears this approach can have a beneficial impact for the athlete (Philips et al.,  
586 2011). Milk could therefore be an economical, practical, and efficacious alternative to  
587 isotonic sports drinks post exercise, particularly flavored milk that contains added simple  
588 sugar, promoting fluid retention, carbohydrate to restore muscle glycogen, and high-quality  
589 proteins to repair and facilitate adaptive changes in protein synthesis (Philips et al., 2011).

590 Nutritional strategies for competition centre on preparing the body for the demands of  
591 prolonged exercise and should be considered within a periodized training plan mapped to  
592 key competitive goals (Zaryski and Smith, 2004). During endurance races, riders may be in  
593 the saddle cumulatively for periods of between 7 and 10 hours for a 160km race, therefore  
594 utilizing a suitable strategy to prevent the onset of fatigue through nutritional deficits and  
595 to prevent dehydration are essential. Costa et al. (2018; 2014; 2013) have consistently  
596 reported that athletes possess an inadequate nutrition status due to factors such as the  
597 absence of nutrition education, ignoring the development of symptoms during racing e.g.  
598 appetite suppression, taste fatigue, and gastrointestinal symptoms, and practical logistical  
599 race issues such as, inadequacy of food preparation facilities, time, and/or motivation. The  
600 impact of logistical factors could be exaggerated in endurance riding, as often riders will  
601 have to deal with practical race issues, taking care of the horse and tend to prioritize the  
602 horse's nutrition and hydration status, rather than considering their own. In a trained athlete,  
603 generally carbohydrate stores amount to ~2000 calories, which can support 2 to 3 hours of  
604 exercise, depending on exercise intensity (Applegate, 1991). This is insufficient for the  
605 ultra-endurance athlete including the endurance rider who will be riding in races for longer  
606 than this. Therefore glycogen super-compensation strategies are necessary to prevent poor  
607 performance and the risks associated with this, including rider safety and poor rider

608 decision-making resulting in negative equine welfare. Glycogen super-compensation has  
609 been documented in runners and cyclists through carbohydrate loading combined with a  
610 tapered training regime, some athletes benefit from having a meal 1 to 4 hours prior to  
611 competition (1 to 4.5g per kg bodyweight of carbohydrate) and ensuring fluid and energy  
612 intake are maintained during competition (Vitalie and Retzon, 2019; Applegate, 1991). This  
613 is the equivalent of 0.3 to 1.1g/hr of carbohydrate, or for the average carbohydrate drink  
614 (normally 5 to 10% carbohydrate) a rate of 150 to 250ml every 15 to 20 minutes (Costa et  
615 al., 2019). Recent studies also suggest the source of carbohydrate can be influential to  
616 performance, with glucose-fructose carbohydrate blends (e.g. 1:1 to 2:1 ratios) producing  
617 superior carbohydrate oxidation and performance over single blends (e.g. glucose alone)  
618 (Costa et al., 2019).

619 It should also be noted that there are different factors that increase energy needs above  
620 normal baseline levels which riders should consider when competing and training. These  
621 include the climate where they train and during races, exposure to cold or heat and humidity  
622 will impact on energy and fluid requirements. Furthermore, fear, stress, high altitude  
623 exposure, some physical injuries, specific drugs or medications (e.g. caffeine and nicotine),  
624 increases in fat-free mass, and possibly the luteal phase of the menstrual cycle can also  
625 result in increased rider energy demands (Manore and Thompson, 2015).

626 The consumption of vitamin and minerals during training and competition to improve  
627 athletic performance is common among endurance athletes (Powers et al., 2011;  
628 Williams, 2005). Prolonged periods of training and competition place large energy  
629 demands on athletes accompanied by a high turnover of vitamins through sweat losses,  
630 metabolism, and the musculoskeletal repair process (Knez and Peake, 2010). Consuming  
631 sufficient quantities of quality food in the diet to meet these increased needs can be  
632 challenging for some athletes, especially in disciplines where weight restrictions apply.  
633 Consequently, antioxidant supplementation is a common practice in athletes to prevent  
634 exercise-induced oxidative damage and to enhance muscle recovery and performance  
635 (Peternelj and Coombes, 2011; Knez and Peake, 2010); however consistent evidence of  
636 their efficacy is lacking. Knez and Peake (2010) found the levels of vitamins in male and  
637 female ultra-endurance athletes met or exceeded general population dietary reference  
638 intakes, with the exception of vitamin D. Across this population, 60% of athletes reported  
639 using vitamin supplements, of which vitamin C (97.5%), vitamin E (78.3%), and  
640 multivitamins (52.2%) were the most commonly used supplements. Vitamin D deficiency  
641 impairs muscular performance, especially in athletes who train or participate in indoor  
642 sports (Powers et al., 2011). In athletes who are deficient in vitamin D, supplementation  
643 could potentially improve athletic performance but care should be taken as excess levels  
644 are toxic (Bartoszewaska et al., 2010); however whether athletes should use antioxidant  
645 supplements remains an important and highly debated topic. Minerals are inorganic  
646 substances essential for a wide variety of metabolic and physiologic processes in the  
647 human body including muscle contraction, cardiac rhythm, nerve impulse conduction,  
648 oxygen transport, oxidative phosphorylation, enzyme activation, immune functions,  
649 antioxidant activity, bone health, and the acid-base balance of the blood (Williams, 2005).  
650 Calcium and iron are the two minerals most likely to be deficient in athletes, especially  
651 younger and female competitors (Williams, 2005). Osteoporosis can occur due to  
652 inadequate calcium intake and / or increased calcium losses; especially at risk in girls and  
653 women who can develop the female athlete triad: disordered eating, amenorrhea and  
654 osteoporosis (Williams, 2005). Calcium and vitamin D supplementation concurrently are  
655 recommended for individuals who are deficient (Gremion et al., 2001). Iron deficiency  
656 anemia is more common in athletes and can be related to myoglobin leakage,

657 gastrointestinal losses, sweat losses, or heavy menstrual losses; however the benefits of  
658 supplementation depend on the iron status of the individual and is warranted where  
659 anemia is present (Williams, 2004). Arguments for and against vitamin and mineral  
660 supplementation exist and additional research will be required to firmly establish whether  
661 antioxidant supplementation is beneficial or harmful to athletes (Philips et al., 2011).  
662 Currently limited scientific evidence exists to recommend antioxidant supplements to  
663 athletes and athletes' focus should be on consuming a well-balanced, energetically  
664 adequate diet that is rich in antioxidant-containing foods (i.e. whole grains, fruits,  
665 vegetables, nuts, and seeds) (Philips et al., 2011).

666  
667 Hydration status of the endurance rider also needs to be maintained during competition.  
668 Increased exercise metabolism can lead to hypo-hydration (2-5% body water loss) through  
669 excess heat production and subsequent increased sweating (Nikolaidis et al., 2018). The  
670 following equation can be used to determine sweat related water losses during training and  
671 competition:

672 Sweat loss (L) =  $\frac{1}{4}$  Body mass before exercise (kg) – Body mass after exercise (kg) +  
673 (Volume of fluid consumed during exercise [L]) – (Urine volume, if any [L])

674 Sweat rate (L/h)  $\frac{1}{4}$  Sweat loss (L) / Exercise duration (h) (McDermot et al., 2017)

675 There is evidence to demonstrate that “drinking to thirst” (consuming fluids as thirst dictates  
676 (McDermot et al., 2017) during ultra-endurance activities, even under hot ambient  
677 conditions, will allow maintenance of proper hydration (Hoffman et al., 2018). However,  
678 anecdotal reports suggest endurance riders and their support team will often prioritize horse  
679 hydration and potentially forget about their own thirst. Dehydration can result in fluid and  
680 electrolytes imbalances which can develop and adversely impact individuals' health and  
681 performance. Dehydration can impair exercise performance and contribute to serious heat  
682 illness, and hyponatremia can produce grave illness or even death (Sawka et al 2000).  
683 Furthermore, care should be taken over what type of fluid replacement drink is utilized; for  
684 example commercial sports drinks are not recommended (Hoffman et al., 2018). It is also  
685 advisable that the endurance rider estimates the fluid volume they need to consume between  
686 water sources to support their thirst as over hydration can also be detrimental to health and  
687 developing a hydration protocol (Table 7) is recommended (Casa et al., 2000). Athletes  
688 should consider their bodyweight in association with exercise intensity and climatic  
689 conditions when developing hydration strategies (Nikolaidis et al., 2018). Using the  
690 instinctive thirst mechanism and monitoring bodily parameters such as body weight, urine  
691 color, race pace, body temperature, and environmental temperature can help the athlete fine  
692 tune their individual hydration needs and avoid complications such as exercise-associated  
693 hyponatremia (Vitalie and Retzin, 2019); likewise, how fluids are provided to riders should  
694 be considered. Anecdotally many riders will not carry fluids *in situ* on their person when  
695 racing, for fear of ‘altering the balance’ and carrying more weight than necessary. Therefore  
696 fluid replacement is grabbed at crew points or riders wait until veterinary gates to take fluid  
697 on board, which may not be the most appropriate strategy to maintain optimal hydration.  
698 Riders should also be able to recognize the early signs and symptoms of exercise-related  
699 hypo-hydration; these include thirst and general discomfort or complaints (approximately  
700 2% body mass deficit), followed by flushed skin, weariness, cramps, and apathy and then  
701 more severe symptoms at greater water deficits (more than 2% body mass loss): dizziness,  
702 headache, vomiting, nausea, heat sensations on the head or neck, chills, and dyspnea  
703 (McDermot et al., 2017). Further investigation to explore optimal strategies and the best  
704 methods to ensure endurance riders retain positive hydration status are warranted across all

705 levels of the sport and especially for races in climates which present increased thermal and  
 706 humidity challenges to the rider.

707 Table 7: Factors to consider when developing a hydration protocol for athletes based on the  
 708 National Athletic Trainer’s Association Hydration Position Statement (McDermot et al.,  
 709 2017)

<b>Hydration protocol for athletes</b>	
<p>Monitor indicators of hydration</p>	<ul style="list-style-type: none"> <li>• Perception of thirst at rest, using scale of 1 [not thirsty at all] to 9 [very very thirsty]) (Note, normally thirst increases when 2% Hypo-hydration is approached and decreases when fluid balance is restored to a loss of less than 2%)</li> <li>• Accurately measure body mass using a valid and reliable floor scale pre- and post-training / competition or compare to euhydrated baseline (Note: 3 days consecutive euhydrated baseline measurements are needed to negate the impact of variation related to circadian rhythms)</li> <li>• measure urine concentration (colour or ideally osmolality ) and volume using the first morning urination</li> <li>• measure body fat percentage using a trained technician</li> </ul>
<p>Pre-race</p>	<ul style="list-style-type: none"> <li>• Start euhydrated</li> <li>• Supplement carbohydrates or electrolytes (or both) to rehydration fluids prior to participating in exercise sessions &gt;1 hour or including intense intervals or taking place in extreme environments</li> <li>• supplement fluids containing carbohydrates and electrolytes during extended training bouts and competition</li> <li>• individual assessment of sweat-electrolyte concentrations should occur before considering sodium supplementation</li> <li>• eat a balanced diet</li> <li>• be mindful of the impact of individual cues on hydration status, such as thirst, body weight, urine color, and voiding frequency</li> </ul>
<p>Hydration during a race</p>	<ul style="list-style-type: none"> <li>• maintain hydration and not allow more than a 2% body mass loss</li> <li>• limit body mass losses to less than 2% throughout activity but without gaining weight during exercise</li> <li>• consume enough fluid to approximate personal sweat volume losses and avoid both excessive body fluid losses and overconsumption of fluids</li> <li>• know your personal sweat rate and develop a hydration strategy based on individual needs (i.e. calculate expected fluid losses and ensure sufficient replacement fluid is ingested)</li> <li>• apply short-term revisions to hydration strategies in response to unanticipated events e.g. gastrointestinal upset, discomfort, fluid availability, environmental conditions, fluid type</li> <li>• when individual sweat rates are not known, drinking to thirst during activity represents a safe strategy to prevent overdrinking</li> </ul>

After the race	<ul style="list-style-type: none"> <li>• rapid replacement of fluid post-exercise to restore euhydration, improve recovery and decrease fatigue</li> <li>• Up to 150% of the estimated fluid deficit needs to be consumed to effectively replace fluid losses after exercise over a short recovery period (less than 4 hours)</li> <li>• on an individual basis consider carbohydrate, protein and / or electrolytes in the diet or fluids to assist in restoring fluid balance and muscle glycogen levels, and promote muscle recovery</li> <li>• note: the exact volumes of replacement fluids will depend on solid food ingestion quantity and timing</li> <li>• Caffeine does not compromise rehydration or increase urine output when consumed in small quantities (up to 3 mg/kg) during or after exercise</li> </ul>
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710

711 Endurance riders have to weigh in pre-competition unless competitions apply to the FEI for  
712 approval to add sub-categories or eliminate weight allowances prior to the event; acceptable  
713 rider weight allowances vary according to race level (refer to Table 5) and include all riding  
714 equipment (excluding the bridle) (FEI, 2020a). The mandatory minimum weight limits were  
715 introduced by the FEI in 2017 and have been the topic of heated debate in the sport, with  
716 some national federations suggested they disadvantage lighter, smaller framed female riders  
717 who have to carry weight to achieve them (Horsetalk, 2020). In contrast heavier, perhaps  
718 male riders, may be tempted to diet or fast to attain the allocated weight; a strategy which  
719 should be avoided due to the detrimental effect on health and performance. Whilst no  
720 studies to date have examined the impact of suboptimal energy and hydration status on the  
721 endurance rider, research has explored the impact of nutritional and weight-making  
722 practices in professional jockeys in horseracing (Dolan et al., 2011; Martin et al. 2017).  
723 Wilson et al. (2014) concluded that rapid weight loss practices had serious adverse effects  
724 on jockey mental and physical health, and performance. Endurance riders are recommended  
725 to consult with a registered dietitian or nutritionist for a personalized nutrition plan (Thomas  
726 et al., 2016) and for individuals where weight loss is necessary, athletes are advised to  
727 accomplish it gradually, at a rate of approximately 0.5 kg/week. In order to induce this  
728 weight loss, an energy deficit corresponding to about 500 kcal/day will be required. This  
729 can be obtained by calorie restriction, increased energy expenditure, or both approaches.  
730 Furthermore, such interventions should be programmed to occur in a non- competitive  
731 period of the training to minimize loss of performance (Garthe et al., 2011; Rankin, 2002).  
732 It is likely that some endurance riders are competing with an inadequate nutritional status  
733 for the demands of endurance racing. Alternatively, lightweight riders may need to add and  
734 carry additional weight to achieve the standard weight allowances. It is not always possible  
735 to attach all the additional weight required to the horse and the use of diving belts and  
736 weights is commonplace in lightweight riders. Little is known about the physiological  
737 impact of additional weight, especially in a sport where some competitors may be as young  
738 as 14 years old or how ‘dead’ weight impacts on the performance of the horse and rider.  
739 Going forwards, further research is required to accurately ascertain the nutritional demands  
740 of endurance riders both during training and in competition, to enable bespoke nutritional  
741 strategies to support the rider as an athlete to be devised.

742

743 *Psychological demands of endurance riding*

744

745 Successful endurance performance relies on effective rider decision-making and pacing  
746 strategies, and the ability to consistently re-evaluate strategy during race conditions to  
747 maximize performance and manage the health and welfare of the horse (Renfree et al.,  
748 2014; Tabor and Williams, 2017; Marlin and Williams, 2018a, b). Athletes who do not  
749 implement pacing strategies, or who are easily influenced by other competitors' actions,  
750 are likely to report premature fatigue, resulting in loss of their own and their horse's  
751 performance (Renfree et al., 2014; Brick et al., 2015). Recent studies on pacing strategies  
752 utilized in FEI endurance events have suggested that more aggressive, and variable pacing  
753 strategies, combined with faster loop one speeds, have been linked to a greater risk of  
754 non-completion and withdrawal for metabolic and gait related issues (Bennet and Parkin,  
755 2018; Marlin and Williams, 2018a; Marlin and Williams, 2018b). Throughout a race,  
756 endurance riders are also required to make constant tactical changes to their original race  
757 strategy; however these changes are often based on the horses' performance and physical  
758 monitoring of the equine athlete rather than their own performance (Marlin and Williams,  
759 2018a,b; Renfree et al., 2014).

760

761 Any physical activity is defined by the constant flow of three areas of interconnecting  
762 physical feedback: perceptible interoceptive feedback (organ-based), kinaesthetic  
763 feedback (movement-based) and proprioceptive feedback (spatial cues) (Salmon et al.,  
764 2010). Whilst the endurance rider does not directly receive interoceptive feedback from  
765 their equine partner, research has suggested that due to the predominantly physical  
766 communication between horse and rider, riders often become attuned to their horses'  
767 body sensations, becoming highly sensitive to horses' movement proficiency, gait  
768 mechanics and speed (Jackman et al., 2015; Jackman et al., 2019; Dashper, 2017).  
769 Dashper (2017) refers to this process as kinaesthesia, the complex sensory and motor  
770 communication between horse and rider, whilst Jackman et al. (2019) describes a distinct  
771 'feel' of unity and oneness with the horse. This is not dissimilar to the reported  
772 connections between individual athletes and sport objects in travel sports during flow  
773 states, where it is not unusual to refer to 'the bike and the body as one', blurring the lines  
774 between body and sport (Jackson, 1992, 1995; Jackman et al., 2019). Locomotive  
775 synchrony is also reported in successful paired sports teams whereby athletes are in tune  
776 with their partners' physiological, biomechanical and psychological responses (Jackson,  
777 1992). Therefore endurance riders could utilize kinaesthetic and proprioceptive  
778 biofeedback from the horse during a race to monitor pacing strategy within competition.

779

780 The management of pacing strategies within a race initiates a high neurocognitive demand  
781 for an athlete through consistent cognitive re-evaluation, monitoring of physical effort  
782 (combined with the physical effort of the horse in the case of endurance), decision  
783 making, risk analysis and continued motivation (McCormick et al., 2015). Smirmaul et  
784 al. (2013) suggests there are only two psychological determinants that directly influence  
785 endurance performance: perception of effort and potential motivation. Perception of  
786 effort is defined as the conscious recognition of the sensation of exercise, the appraisal of  
787 significant increases in intensity and duration resulting in a subjective sense of strain,  
788 which is detrimental to endurance performance (Salmon et al., 2010). Whilst research has  
789 reported that perception of effort increases exponentially around the onset of blood lactate  
790 accumulation in human endurance athletes suggesting it is based on purely physical  
791 feedback (Salmon et al., 2010), there is evidence that perception of effort is independent  
792 from peripheral afferent feedback loops (Smirmaul et al., 2013). The psychobiological  
793 model suggests that the perception of bio-feedback and perception of effort are two

794 separate neurological mechanisms (Smirmaul et al., 2013). Therefore athlete perception  
795 of effort in endurance sports is more likely to be hindered by mental fatigue affecting the  
796 central processing of sensory input in the anterior cingulate cortex (ACC) region of the  
797 brain (Macora et al., 2009).

798  
799 Mental fatigue is defined as a psychobiological state caused by prolonged periods of  
800 demanding cognitive activity, such as the continual reassessment of pacing strategies and  
801 biofeedback analysis seen within endurance sports (Macora et al., 2009). Mental fatigue  
802 has been reported to result in increases in perception of effort during a race, resulting in  
803 decreased performance (McCormick et al., 2015). In addition, athletes are likely to  
804 decrease engagement with harder physical tasks when mentally fatigued, such as within  
805 the latter stages of endurance races if an appropriate fitness strategy has not be  
806 implemented, with can limit performance potential (Macora et al., 2009). For equine  
807 endurance events, similarly to ultramarathons or phase looped endurance sports, there is  
808 a likelihood that during the course of the event, riders will experience time away from  
809 other competitors. Research suggests that the presence of others during endurance sport  
810 increases drive and arousal, and reliance on dominant behavior and motor skill patterns,  
811 making the completion of the sport 'feel' easier to an athlete, reducing mental fatigue  
812 levels (Spence et al. 1956a; Spence et al. 1956b; Bishop et al., 2001; Strauss 2002).  
813 Without the presence of competitors, endurance riders may experience higher levels of  
814 mental fatigue and therefore decreased motivation to continue (Spence et al. 1956a;  
815 Spence et al. 1956b; Bishop et al., 2001; Strauss 2002), which could negatively influence  
816 their ability to complete the race. Within equestrian endurance, the unique biofeedback  
817 mechanisms from horse to rider could result in higher levels of cognitive demand and  
818 mental fatigue (McCormick et al., 2015), combined with competition isolation, resulting  
819 in increased perception of effort in endurance riders through personal mental fatigue  
820 rather than based on biosensory input from the horse causing them to alter speeds or  
821 strategy incorrectly mid-race.

822  
823 Potential motivation, based on Motivational Intensity Theory (Brehm, 1989), is  
824 determined as the greatest amount of effort an athlete will use to satisfy their motives  
825 (McCormick et al., 2015). When there is a known endpoint to endurance exercise, i.e.  
826 closed loop tasks, such as completing loops within an endurance competition, athletes are  
827 likely to be more motivated to complete, offsetting any potential negative biofeedback,  
828 such as muscle soreness or pain (Smirmaul et al., 2013; Renfree et al., 2014). However,  
829 at lower intensity exercise, increased motivation associated with a perceived endpoint of  
830 exercise can result in athletes underestimating physical exertion, resulting in them starting  
831 races too quickly, and reaching peak performance too early within a race (Hall et al.,  
832 2005; Renfree and St. Clair Gibson, 2013). This phenomena has been reported in equine  
833 endurance research, with Bennett and Parkin (2018) reporting that faster riding speeds in  
834 loops one and two were associated with detrimental outcomes, suggesting that endurance  
835 riders are at increased risk of underestimating horses' physical exertion.

836  
837 Associative and dissociative strategies are widely utilized by endurance athletes,  
838 alongside psychological skills training, at all levels to attempt to enhance performance  
839 (McCormick et al., 2015). Associative strategies, often implemented by elite athletes,  
840 require constant monitoring of body sensations and the use of biofeedback to regulate or  
841 adjust pace (McCormick et al., 2015). Dissociative strategies are more commonly seen in  
842 non-elite endurance athletes, who use internal or external coping mechanisms, such as  
843 daydreaming, music or scenery, to direct attention away from unpleasant sensations



(Brick et al., 2014; McCormick et al., 2015). Whilst dissociation is more commonly reported to be correlated to a decrease in perceived effort, the limited engagement with biofeedback can result in errors in early race pacing strategies leading to poor performance (Renfree et al., 2014). For endurance riders who do not directly experience those unpleasant physical sensations that may limit equine performance resulting in metabolic or gait eliminations, the risk of utilizing dissociative strategies to avoid reflection on personal fatigue may be seen, resulting in failure to identify the horses speed during loops which could negatively impact performance (Bennet and Parkin, 2018; Marlin and Williams, 2018a,b). Psychological recommendations for successful performance in equestrian endurance would include riders using associative strategies, such as monitoring equine biofeedback through pacing and equine heart rate (Marlin and Williams, 2018a; Marlin and Williams, 2018b), to regulate and adjust pace during their race whilst aiming to decrease reliance on distraction techniques during their ride. Within equestrian endurance, the use of monitoring devices for pacing, speed and physiological demand are permitted under FEI rules (FEI, 2020a), which should further allow riders to focus more on associative strategies. Further research should also explore the current use of associative and dissociative strategies in FEI endurance riders and the implications of psychological status and fatigue on race tactics including pacing, particularly related to loop one speed.

## **Conclusion**

To date, the core focus in endurance riding has been on how the rider and their associated support team execute their duty of care and manage the health and welfare of the equine athlete with less emphasis placed on the rider. Successful endurance riding requires an effective partnership to be established between horse and rider. Within this partnership, adequate rider health and fitness are key to optimal decision-making in respect of not only their horse in training and competition, but just as importantly with respect to how they manage themselves as an athlete. In the absence of discipline specific research, the aspiring endurance athlete should take a more holistic approach, managing their own performance by adopting training and competition strategies used effectively to date by ultra-endurance athletes to maximize their own and their horse's performance. Targeted management for superior rider performance can underpin more effective decision-making promoting ethical equitation practices and optimizing competition performance. The responsible and competitive endurance rider needs to consider how they prepare themselves adequately for participation in the sport. This should include engaging in appropriate physiological training for fitness and strength and conditioning. Alongside planning nutritional strategies to support rider performance in training and within the pre-, peri- and post-competition periods, to promote superior physical and cognitive performance, and to prevent injury. Applying an evidence informed approach to self-management by the endurance athlete (rider) will ultimately support horse and rider partnerships to achieve to their optimal capacity, whilst maximizing both parties physical and psychological wellbeing.

Despite the popularity of endurance riding, endurance riders represent an under-researched demographic within equestrianism. This presents a fundamental issue for riders participating in the sport who wish to engage with performance analysis and evidence informed training and competition strategies, to improve their performance. We would therefore like to issue an edict to the sector, for industry and researchers to come together and rectify this situation through a planned programme of applied research to

894 support the endurance rider in achieving to their full potential, which should, by  
895 association, have a positive impact on their equine partners.

896

897 Conflict of interest: no conflicts of interest exist related to this study.

898

FINAL DRAFT

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