

1 **An evaluation of factors affecting show jumping warm-up on subsequent show**
2 **jumping performance in 1.30m class**

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7

8 **Abstract:**

9 Show jumping causes physical and physiological stress on horses' musculoskeletal
10 structures, which can lead to decreased performance and injury. Appropriate warm-
11 ups can enhance performance, decrease injury risk, as well as increase oxygen kinetics
12 for better efficiency. Despite this, little is known for how warm-up routines affect show
13 jumping performance. Forty-five warm-up routines of show jumpers preparing to enter
14 the show ring were recorded and analysed. Kruskal Wallis analyses with post-hoc
15 Mann Whitney U tests identified if the number of classes combinations competed,
16 types of jumps attempted, warm-up duration, and time spent in each gait during the
17 warm-up varied with rider and horse sex and age, and faults. Spearman correlations
18 assessed if relationships occurred between warm-up duration and content, and the
19 number of faults in the show ring, and horse age. Warm-up ranged from 3:51 to 62:46
20 minutes (median 15:09 minutes) and included at least two jumps (range 2 - 15). Walk
21 was the most common gait, while upright fences were jumped the most. Knocking
22 down or refusing a fence when warming up did not affect performance. Male riders
23 jumped uprights twice as much as female riders ($p < 0.03$) but this did not impact their
24 performances. Jumping a class prior to the 1.30 affected warm-up, competitors spent
25 longer on the flat before jumping in they had competed earlier in the day ($p < 0.05$)
26 and had fewer jump attempts if they had competed in the class just prior to the 1.30m
27 ($P < 0.007$). Even though no significant differences were detected, combinations which
28 accumulated > 8 faults spent less time warming-up. These results suggest warm-up
29 tactics, riders and horses' age and sex did not influence significantly fault
30 accumulation in the show ring, however warm up routines were influenced by rider
31 decision making and horse age.

32

33

34 Keywords: warm-up, success, jumping, horse, competition, equestrian sport

35

36 No conflicts of interest relate to this work.

37

38 **Introduction**

39

40 Show jumping appears to be the most popular equestrian sport within the three
41 Olympic disciplines with higher competitor numbers than in the other disciplines
42 (Gorecka-Bruzda et al., 2015). The goal of a show jumping competition is for horse
43 and rider combinations of mixed age and gender to complete a course of obstacles. In
44 order to be successful, they must complete the course without scoring any penalties or
45 faults. Faults are accrued for knocking down or refusing a fence, or taking longer to
46 finish than the allocated time. In the UK, show jumping courses consists of at least
47 seven fences of variable height and technicality depends on the competition level
48 (British Show jumping, 2016).

49

50 Technical skills, experience, power, speed and endurance are required from both the
51 horse and rider to compete successfully in show jumping (Ferraz, 2010; McBride et
52 al., 2012; Peeters, 2013). Success in show-jumping competition is therefore affected
53 by the physical ability, fitness level, training level and behavioural responses of the
54 horse to the show environment (Jastrzebska et al., 2017; McGreevy and McLean,
55 2007, Munster 2014). Rider performance is also a critical component of success: rider
56 fitness, personality, skill and decision-making will dictate how horses are ridden
57 around the course and will decide speed, stride patterns and approaches to the fences
58 (Douglas et al., 2012; Rovere et al., 2016; Williams, 2017; Wolframm et al., 2008).
59 Finally, the partnership between individual horse and rider dyads, and how well these
60 partnerships work together, will influence performance (Williams, 2013).

61

62 Physical demands of competition

63

64 During a show jumping course, both the aerobic and anaerobic metabolism will be
65 required for the horse to perform successfully (Williams, 2013). These parameters will
66 be affected by the training methods as well as the natural capacity and fitness level of
67 the horse and will directly affect performance (Munster, 2014; Williams, 2013).
68 During a show jumping round the heart rate, packed cell volume, lactic acid and
69 plasma cortisol level of the horse increase significantly, while the blood glucose level
70 decrease significantly (Lekeux et al., 1991). The increase in heart rate is correlated to
71 the increase of blood lactate level one-minute post jumping which is itself associated
72 with muscle soreness and spasms (Harris et al, 2014; Roberts et al., 2014). When
73 horses were jumped twice on the same day, muscle soreness and spasms have been
74 linked to a decrease of performance (Roberts et al., 2014).

75 Levels of creatine kinase (ck) and aspartate aminotransferase (ast) also show an
76 increase immediately after jumping and up to 24 hours post jumping (Gundasheva,
77 2016). These enzymes increase due to the increase of free radicals from oxidation and
78 are believed to be linked to muscle soreness and damage (Jahn et al, 2001; Teixeira-
79 Neto et al. 2008). An efficient warm-up increases the use of the aerobic metabolic
80 pathway leading to a lower heart rate and respiratory rate, diminishing glucose
81 expenditure as well as reducing lactic acid accumulation in a horse's muscles, reducing
82 the onset of fatigue (Jansson, 2005; Mukai et al, 2008; Mukai et al, 2010).

83

84 In order to perform to their maximal capacity, the equine athlete should also be free
85 from pain and injury (Dyson et al., 2018, Williams, 2017). In show jumping, the
86 requirement to complete numerous jumping efforts in competition exposes the horse
87 to increased ground reaction forces (GRF) and loading in the trailing forelimb (> 180%

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88 increase in GRF) and hindlimbs (> 130% increase in GRF) during take-off, and a
89 further 200% increase in the forelimbs on landing (Hernlund et al, 2013). The resultant
90 repetitive stress and high concussion forces associated with jumping can potentially
91 cause damage to the distal limbs (Dyson et al., 2002; Herlund et al., 2013; Parkes et
92 al., 2012). Injuries to horses result in days lost from training as well as incurring a
93 financial loss (Eegenval, 2013). Minimizing injury risk should therefore be a priority.
94 Research in human sports has shown that certain types of warm-up can reduce the risk
95 of injury as well as improve performance (Safran, 1989; Olsen, 2005; McGowan et al.,
96 2015). The term warm-up in sport is defined as a period of preparatory exercise in
97 order to enhance subsequent competition or training performance (Hedrick, 1992).
98 Three different factors are recommended for human exercise warm-up routines: 1) a
99 period of aerobic exercise to increase body temperature; 2) a period of sport-specific
100 stretching to stretch the muscles to be used in the subsequent performance; 3) a period
101 of activity incorporating movements similar to those to be used in the subsequent
102 performance (Altavilla, 2018). It is recommended there should be no longer than a 15
103 minutes break between the warm-up and the main competition. For human athletes if
104 a break occurs post warm-up then 2 minutes of active re-warm-up, a short jog and few
105 jumps should be sufficient to gain maximum benefits from the warm-up (Silva, 2018).
106 Whether the warm-up is passive (raising muscle or core temperature) or active
107 (involving exercise), the main goal is to increase body temperature which will increase
108 muscle temperature, increasing blood flow and oxygen intake by the muscles. A higher
109 body temperature will also increase the sensitivity of nerve receptors as well as the
110 speed of nervous impulse (Shellock, 1985; Kenney et al, 2011), enhancing
111 performance potential.

112 Different types of warm-up such as active versus passive and low versus high intensity
113 exist for human athletes and depending on the final goal, the warm-up type used should
114 vary for optimal performance in different disciplines (Bishop, 2003; Faigenbaum,
115 2005; McGowan et al., 2015). Similarly, different types of warm-up routines can
116 influence the performance of the equine athlete depending on the final goal, breed and
117 discipline of the horse (Jansson, 2005; Murray et al., 2006). In human subjects, an
118 active warm-up consisting of running 15 minutes at 60 or 70% VO_{2max} has been shown
119 to increase anaerobic performance compared to no warm-up or a warm-up at 80%
120 VO_{2max} (Stewart, 1998). Similar factors have been observed during the warm-up of
121 dressage horses prior to a competition where horses were walked, trotted and cantered
122 before practicing the skills and movement required in their dressage test (Murray,
123 2006).

124

125

126 Role of the warm-up in show jumping

127 Different studies have shown that the warm-up duration of show jumpers varies from
128 5-10 minutes (Dyson, 2018) to 12-27 minutes (Tranquille et al, 2014). The content and
129 duration of the warm-up appears to depend on the experience level of the rider as well
130 as on the competition level (Murray et al, 2006; Whitaker et al, 2008). Elite dressage
131 riders were shown to warm-up longer than novice riders prior to a dressage test and
132 the time spent in each gait varies depending on the level (Murray, 2006). Elite show
133 jumpers have been observed to warm-up asymmetrically, spending more time in the
134 left canter and jumping on average 13 fences prior to entering the show ring

135 (Tranquille, 2014 et al; Tranquille et al., 2009). Implementing an effective warm-up
136 regimen to prepare for specific show jumping classes could improve performance
137 and reduce the number of days lost to training due to injuries (Dyson, 2018; Egenvaal
138 et al, 2013; Harris et al., 2014). Despite this limited research has evaluated the effect
139 of warm-up characteristics on performance in show jumping, therefore the aim of the
140 current study was to investigate if the warm-up routines of show jumpers competing
141 in a 1.30m class influenced their competition performance measured by fault
142 accumulation.

143

144 **Materials and methods**

145

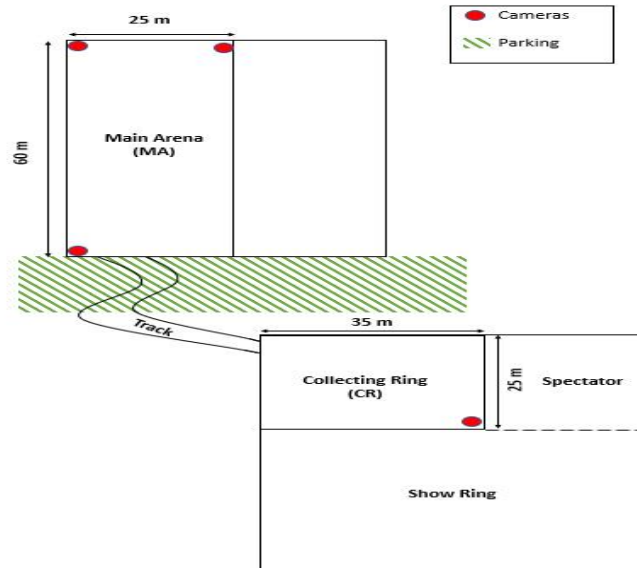
146 The warm-ups of all competitors preparing to compete in a British Show Jumping
147 1.30m class in a competition centre in the South West of England were recorded using
148 video cameras. The study took place over two different affiliated British Show
149 jumping events, fifteen days apart including three 1.30m classes. Class A took place
150 during the first competition and Class B and C were both events within the second
151 competition which took place on two successive days. These classes were selected for
152 data collection in order to limit as much as possible the potential confounding effect
153 of rider and horse experience disrupting the data (Peeters, 2013). In the first show
154 (class A), drawn order was not used, participants could come in the warm-up arena
155 and put a number on the board which would define their drawn order. At the second
156 show (Class B and Class C), drawn order was used so riders were allocated a time slot
157 to be ready to enter the ring. Ethical approval for the study was granted by the Hartpury
158 University Ethics Committee. Permission to record the riders during their warm up
159 was granted by the show organizers and participating riders.

160

161 Four video cameras were set up in the arenas and used to record the warm-up of all
162 participants in Class A, B and C. Horse and rider combinations used two arenas to
163 warm-up prior to jumping the class in a third arena (show ring) (Figure 1). For all three
164 classes, the warm occurred exactly in the same manner. Initially, horses were warmed
165 up in an indoor arena (MA) of 60m by 25m with a synthetic Andrews Bowen surface
166 (Andrew Bowens Ltd, Singleton, United Kingdom). Riders had free access to a single
167 upright and a single oxer fence. A maximum of 12 horse and rider combinations were
168 allowed into this arena at any one time, and there were no restrictions on when
169 combinations began their warm-up in relation of the drawn order for jumping.
170 Approximately 5 minutes before the scheduled order, combinations were called into
171 the collected ring (CR) (25m by 35m, Andrews Bowen surface) situated alongside and
172 connected to the show arena. To access the CR, riders had to cross the lorry parking
173 and follow a downward track approximately 150m long. Within the CR, riders again
174 had access to an upright or oxer fence and were allowed to jump them as many times
175 as they wished until they were called into the show ring.

176

177



178

179 Figure 1: Set up of the infrastructures and the cameras for the study

180

181 Experimental set up

182

183 Four video cameras (three cameras Sony HDR-CX405; one Sony HDR-CX330E; one
184 Sony HDR-CX190E; one Sony DCR SR15; 60 frames per second) recorded warm-up
185 routines. The use of video cameras minimized human error and allowed data to be
186 collected from the two warm-up arenas used simultaneously (Pierard, 2015).
187 Concurrently a single experienced observer was stationed at the entrance of the main
188 warm-up arena (MA) and noted the name of the riders, colour of their horses and tack
189 used. This enabled horse and rider combinations to be recognized on the camera when
190 the warm-up routine were analysed. Three cameras were installed in three corners of
191 MA to prevent blind spots when videoing; one camera was located in the back-right
192 corner of CR where the gate of CR and the fence were clearly visible. (Powers, 2005).
193 All the cameras were set on tripods and located behind a barrier to avoid any incident
194 with the horses (Pierard, 2015). Footage was recorded simultaneously from all cameras
195 once riders entered the MA to commence their warm-up or the CR to continue their
196 warm-up. To enable the height of jumping efforts used during the warm-up to be
197 calculated during data analysis, reference markers were positioned on the fence wings
198 at a height of 1m (blue tape) and at 1.20m (yellow) in both MA and CR.

199

200 Horse and rider combination selection

201

202 Rider sex and horses' age and sex were also recorded from the competition entries.
203 The identity of horse and rider combinations and the time they entered the MA and the
204 CR were noted by an observer. All combinations were video-recorded for the duration
205 of the warm-up to enable subsequent footage from eligible horse and rider
206 combinations to be analysed. To be included in the study, combinations had to warm-
207 up in the MA with no break (e.g. no exiting MA and then coming back in a few minutes
208 later) only leaving the MA when they were called to the CR by the stewards and going
209 directly there. Horses also had to be ridden during the warm-up by the riders
210 competing them in the show ring in order to avoid extra external factors affecting the
211 data. Horses that expressed nervous or conflict behaviours were automatically
212 excluded from the study to limit external factors affecting the results (Gorecka-Bruzda,

Influence of warm-up on show jumping performance

213 2015). A total of forty-five warm-up routines were eligible for observation across 27
214 horse and rider combinations.

215

216

217 Video analysis

218

219 For the twenty-seven combinations that met the inclusion criteria, the warm up for
220 each horse and rider dyad was studied individually. From the video footage recorded,
221 a consistent analyst noted the amount of time horses were ridden in each gait in the
222 MA including walk, trot and canter periods, as well as the duration combinations stood
223 still or were hand walked during the warm-up. The total time spent in each gait, total
224 duration of the warm up and time spent working on the flat before jumping in the MA
225 were calculated using Microsoft Excel Version 2010. Practice fence type was defined
226 as: cross poles (any height), upright lower than 1m (U<1), upright between 1 and
227 1.20m (U1-1.20), upright above 1.20m (U>1.20), oxer lower than 1m (O<1), oxer
228 between 1m and 1.20m (O1-1.20) and oxer over 1.20m (O>1.20), height (m) and
229 number of jumps completed, as well as the time the dyad started jumping were also
230 recorded. If the horse knocked a pole or refused a fence, it was recorded as a jumping
231 fail. In CR, the number of jumps, height and type of fence were recorded and analysed.

232

233 To enable the impact of jumping a preceding class on the same day of competition,
234 horse and rider combinations who had competed the class just preceding the 1.30m
235 were identified as Group 1, those who had competed two classes prior to the 1.30m
236 were placed in Group 2 and those who only competed in the 1.30m class made up
237 Group 3. The competitive performance of horse and rider combinations during the
238 1.30m competition first round was recorded as the number of faults incurred.

239

240 Data analysis

241

242 The mean and standard deviation (sd) of warm-up routines length for each class were
243 calculated using Statistical Package for the Social Science (IBM SPSS computer
244 software version 22).

245 Data did not meet the assumptions of normality, therefore non-parametric analyses
246 were used to assess if differences occurred between warm-up regimes (Field, 2013;
247 Murray, 2006). A series of Kruskal Wallis analyses with post-hoc Mann Whitney U
248 tests identified if differences occurred in the warm-up regimes: jumping effort type
249 and duration in walk, trot and canter related to rider gender and age, horse sex and age,
250 number of classes combinations were competing in prior to the 1.30m class, and
251 success (faults in competition) (Somers, 2015). Spearman correlations determined if
252 relationships existed between warm-up total duration and horse age. Significance was
253 set at $P < 0.05$.

254

255 Results

256

257 Forty-five warm-up regimes were evaluated across 27 riders and 29 horses (Table 1).
258 Fifty six percent ($n = 15$) of riders were male and 44% ($n = 12$) were female. Out of
259 the 29 horses, 20 (69%) were geldings, 6 (21%) were mares and 3 (10%) were stallions.
260 14 warm-up routines were assessed for Class A, 16 for class B and 15 for class C.

261

Influence of warm-up on show jumping performance

262 Table 1: Number of horse and riders who participated in the study (WU: warm up;
263 class A; class B and class C)
264

Rider	Number of warm-ups	Number of horses	Classes competed in
1	3	1	A, B, C
2	2	1	A,B
3	4	2	A, B, B,C
4	2	1	A,B
5	3	1	A,B,C
6	3	2	B,C,C
7	2	1	B,C
8	2	1	B,C
9	2	1	B,C
10	2	1	B,C
11	2	1	B,C
12	2	1	B,C
13	2	1	B,C
14	1	1	A
15	1	1	A
16	1	1	A
17	1	1	A
18	1	1	C
19	1	1	A
20	1	1	A
21	1	1	A
22	1	1	A
23	1	1	C
24	1	1	B
25	1	1	C
26	1	1	C
27	1	1	B

265

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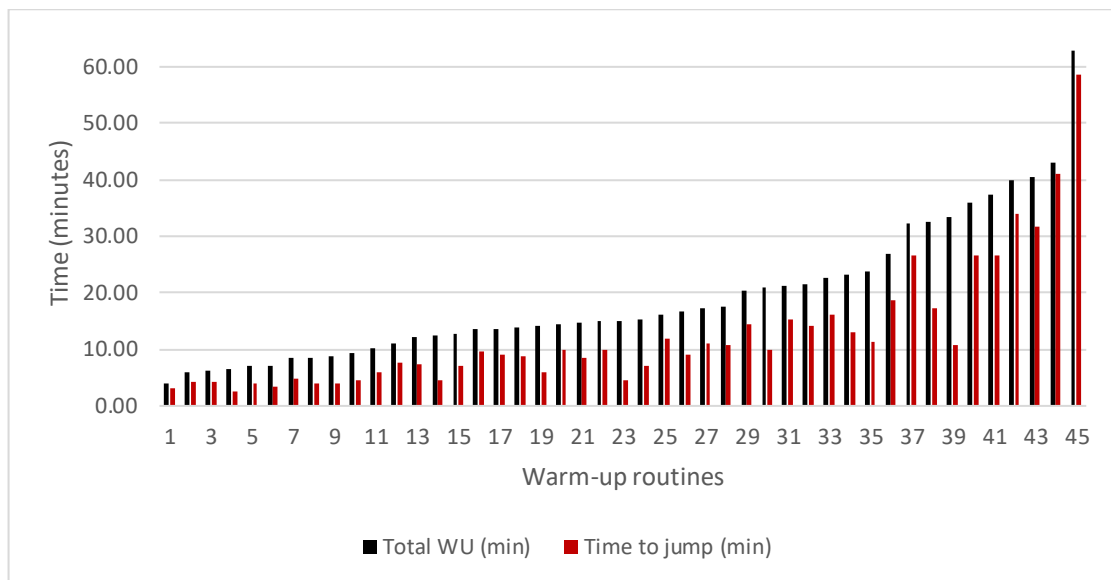
267 Warm-up regimes

268

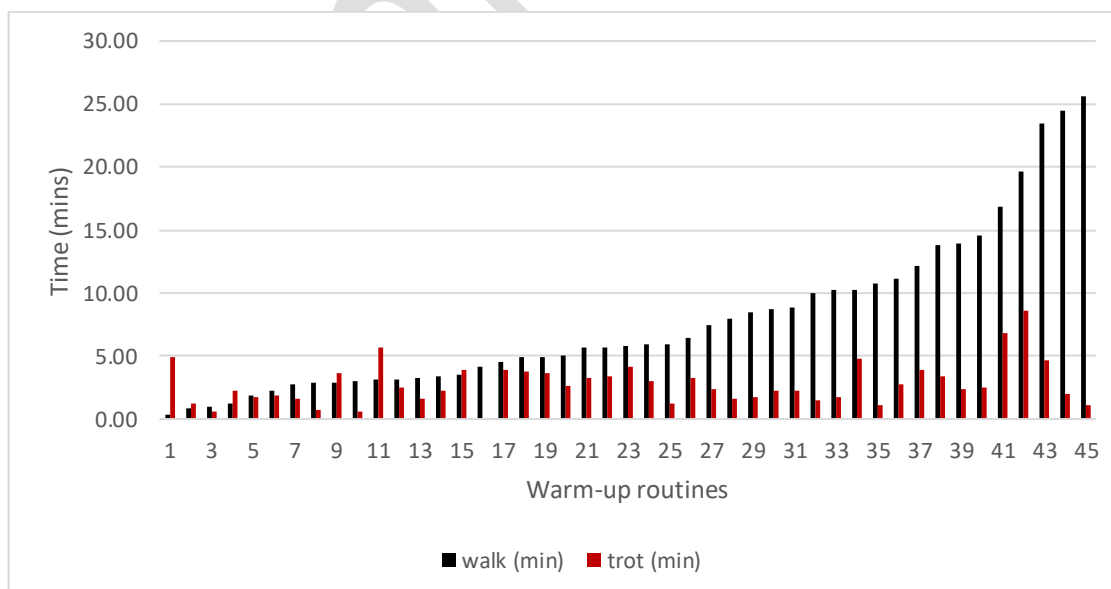
269 Warm-up regimes varied greatly amongst all riders studied in MA, ranging between
270 3:51 to 62:46 minutes with a median duration of 15:09 minutes and mean of
271 18:43±12:24 minutes as observed in figure 2. Twenty-two and ten riders warmed up
272 for shorter than 15 and 10 minutes respectively. Time spent on the flat before jumping
273 varied across riders with a range of 2:39 minutes to 58.34 minutes and a mean of
274 12:19±11:18 minutes (median 9:33 minutes). For 55.6% (n = 25) time spent on the flat
275 before jumping was less than ten minutes. During the warm up, walk was the most
276 prevalent gait used ranging from 3:48 minutes to 25:37 minutes (median 5:48 minutes)
277 and trot was the least used ranging from 0 to 8:39 minutes (median 2:19 minutes)

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278 (Figure 3). The duration of walk and trot was not proportional and varied between each
 279 rider. For 62.2 % of the riders, trot duration was less than 3 minutes during their entire
 280 warm-up. The use of canter ranged from 1:15 minutes to 10:06 minutes (median 5:09
 281 minutes). Over the 45 warm-up routines studied, 67 % riders (n = 30) stood still for 10
 282 seconds or more, including 27 % of the riders (n = 12) who stood still for less than a
 283 minute (range 0 to 37:08 minutes). In class A, 64 % of the riders (n = 9) stood still
 284 (median 0:40 minutes), in class B 62 % of the riders (n = 10) stood still (median 1:37
 285 minutes), in class C 73% of the riders (n = 11) stood still (median 1:19 minutes).
 286



287
 288 Figure 2: Warm-up durations and time spent on the flat for the forty-five combinations
 289 studied in the main arena; mins: minutes
 290



291
 292 Figure 3: Time spent in walk and trot for each rider studied; min: minutes
 293

294 On average riders attempted 9 fences before entering the show ring (range: 2 to 15).
 295 Cross poles were the fences used the least during the warm up in both MA and CR
 296 over the three show jumping classes, with only 23.1 %, 18.7 % and 25 % of the riders
 297 using them in class A, B and C, respectively. Uprights between 1 - 1.20m were used

Influence of warm-up on show jumping performance

298 by all riders observed in all three classes. The number of jump fails were higher for
299 participants of class B and C (18.8 %, 18.8 %) compared to class A (7.7%).

300 All combinations jumped a minimum of two warm-up fences in MA, with the total
301 number of fences ranging between 2 and 14 fences per rider. Typically, combinations
302 elected to jump uprights between 1 - 1.20 m and above 1.20 m followed by oxers
303 between 1 - 1.20 m in the MA warm-up. Over the three classes studied, 352 jumps
304 were attempted in MA, 15 cross poles, 182 uprights and 156 oxers all heights were
305 included, out of which only 9 attempts were fails.

306

307 Seven percent (n = 3) of horse and rider combinations completed no further jump
308 attempts in CR (40 %: 1 jumping efforts; 37.8 %: 2 jumping efforts; 15.5 %: 3 jumping
309 efforts). In CR, uprights above 1.20 m were the type of fence most attempted (68.9 %;
310 n = 31), with a total of 56 uprights of various heights jumped compared to only 17
311 oxers of varied heights, with no cross poles jumped. Out of the 73 fences attempted in
312 CR, only 3 attempts resulted in jump fails.

313

314 Across both warm-up arenas, uprights above 1.20 m were the fences most often used
315 (n = 96) followed by uprights between 1 - 1.20m (n = 76). Overall, combinations
316 completed a minimum of two jumping attempts, range: 2 to 15 jumps (median: 8),
317 with 9 and 10 jumping efforts being the most common approach observed (17.8 %
318 each). Out of the 425 attempts, all jumps mixed, 12 fails were recorded (2.82 %).

319

320 The impact of the rider

321

322 Out of the 27 riders studied, two took part in the three classes with the same horse, 11
323 riders took part in two classes with the same horse and one rider took part in 2 different
324 classes with two different horses. As observed in table 2, duration of the warm-up,
325 time to jump, time spent standing, walking, trotting and cantering varied between
326 riders on different days. Differences between warm up routines of the same rider on
327 different days ranged from 59 seconds to 29 minutes 29 seconds with 50 % (n = 7)
328 having ten minutes or more difference in the total warm-up duration. The number of
329 attempts on fences varied for 78.6 % (n = 11) of the riders ranging from 1 to 6 fences.

330

331

332 Table two: Range of warm up duration, time to jump, stand, walk, trot, canter and
333 range of attempts number; min: minutes

334

Influence of warm-up on show jumping performance

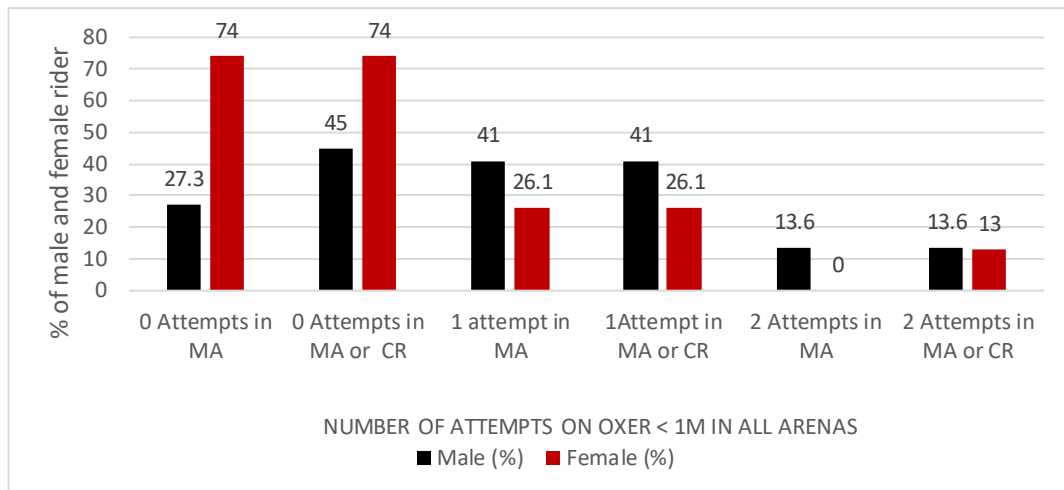
Rider	Range total WU (min)	Range time to jump (min)	Range stand (min)	Range walk (min)	Range trot (min)	Range canter (min)	Range of total number of fences attempted
Rider 1	12:36 to 40:25	4:35 to 31:45	0 to 19:19	3:17 to 11:08	1:40 to 3:55	7:24 to 7:43	9 to 15
Rider 2	43:05 to 62:47	41 to 58:34	21:04 to 37:08	0:48 to 13:50	3:21 to 4:10	3:48 to 10:06	10 to 13
Rider 3a	3:51 to 7:07	3:05 to 3:27	0	1:02 to 1:54	0:39 to 1:41	1:57 to 3:34	5 to 9
Rider 3b	16:03 to 21:21	12:01 to 15:23	0:09 to 3:35	8:01 to 10:17	1:37 to 1:44	7:14 to 6:05	9 to 11
Rider 4	6:15 to 12:44	4:14 to 7:13	0	0:54 to 4:56	1:17 to 3:46	4:04 to 6:12	9 to 12
Rider 5	17:25 to 37:23	10:59 to 26:36	0:17 to 2:31	8:27 to 24:32	1:46 to 4:39	4:14 to 8:59	8 to 13
Rider 6	6:31 to 36 :00	2:39 to 26:42	0 to 44	3:04 to 19:35	0:34 to 8:39	2:53 to 6:02	5 to 10
Rider 7	14:11 to 32:20	5:51 to 26:42	3:23 to 13:37	3:24 to 6:28	2:15 to 3:17	6:08 to 8:41	8 to 11
Rider 8	12:34 to 15:24	8:59 to 7:04	0 to 0:24	3:05 to 8:45	2:13 to 05:37	3:52 to 6:46	8 to 9
Rider 9	16:36 to 17:35	7:07 to 9:08	0:25 to 1:2	5:41 to 10:42	1:03 to 3:23	4:24 to 6:18	10
Rider 10	15:09 to 33:24	4:37 to 10:38	0 to 3:20	7:29 to 25:38	1:09 to 2:20	3:17 to 5:30	9
Rider 11	26:56 to 40:01	18:36 to 34:00	2:39 to 8:17	12:09 to 16:51	3:54 to 6:47	5:06 to 6:54	11 to 12
Rider 12	12:17 to 15:24	7:04 to 7:29	0:09 to 0:24	5:52 to 8:45	2:13 to 3:00	2:10 to 3:42	7 to 9
Rider 13	14:11 to 23:45	5:51 to 11:28	3:23 to 7:53	3:24 to 10:02	1:31 to 2:15	4:59 to 6:08	8

335

336

337 Male riders were nearly twice as likely to jump their horses over oxers during the
 338 warm-up in the MA compared to female riders ($p = 0.03$; 48 % vs. 27 % respectively;
 339 Figure 4).

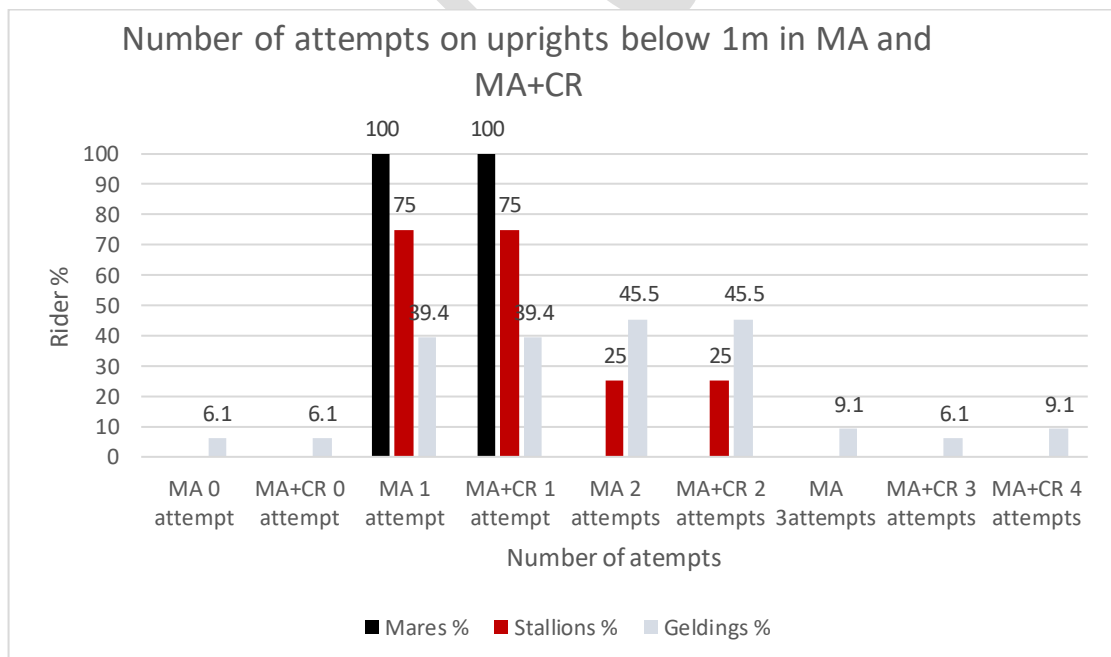
Influence of warm-up on show jumping performance



340
341 Figure 4: Number of attempts on oxers below 1m in main arena or collecting ring for
342 male and female riders; MA: main arena; CR: collecting ring; %: percentage
343

344 Sex and age of the horse

345
346 Differences in warm-up regime were also observed related to horse sex and age (Figure
347 5), however these were only significant for the number of upright fences jumped < 1m
348 ($p = 0.05$). Across MA and for MA and CR combined, geldings were jumped on
349 average 1.5 attempts (median: 2 attempts) while mares and stallions had an average of
350 1.2 and 1.25 (median: 1 attempt). Both mares and stallions had no attempts over fences
351 lower than 1m in CR. Riders who rode geldings always incorporated an upright fence
352 in their warm-up.
353

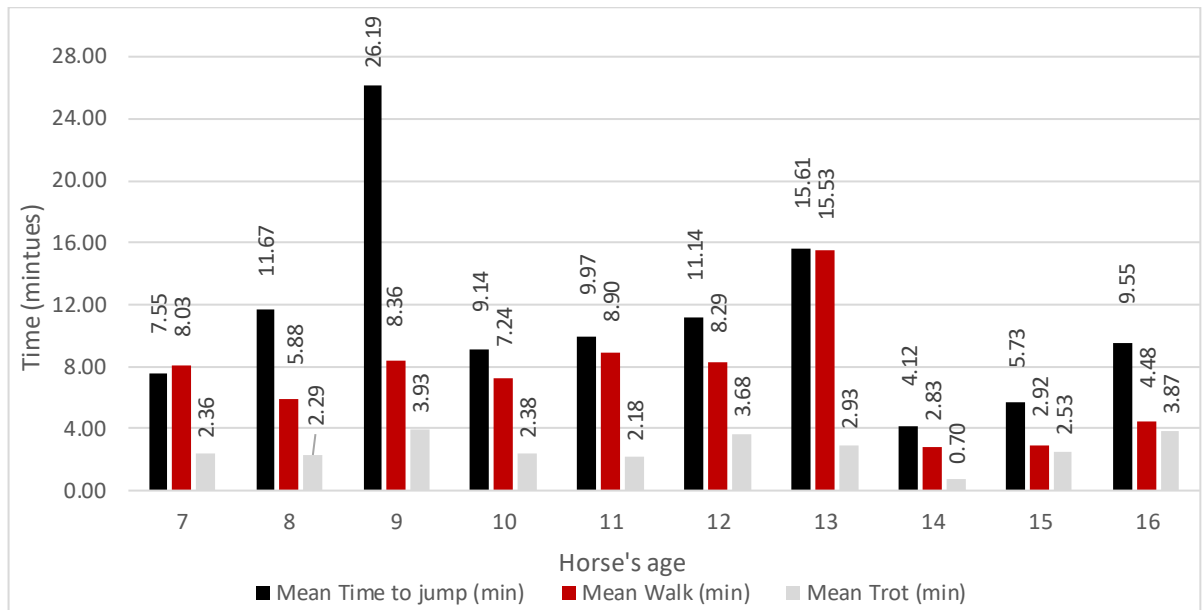


354
355 Figure 5: Number of attempts on uprights below 1m main arena, and main arena plus
356 collecting ring for geldings, mares and stallions
357

358 Significant differences were found between horse age and time to jump ($p = 0.01$) as
359 well as time spent in walk ($p = 0.03$) and trot ($p = 0.045$). As observed in figure 6,
360 horses aged 9 years spent more time working on the flat (mean: 26:11 minutes;

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361 median: 25:10 minutes) before jumping than other age groups. Horses aged 13 years
362 spent more time in walk (mean: 15:32 minutes) while horses aged 14 years and over
363 spent the least time in walk (less than 5 minutes).
364



365
366

367 Figure 6: Mean time spent on the flat before jumping, in walk and trot depending on
368 the age of the horses; min: minutes

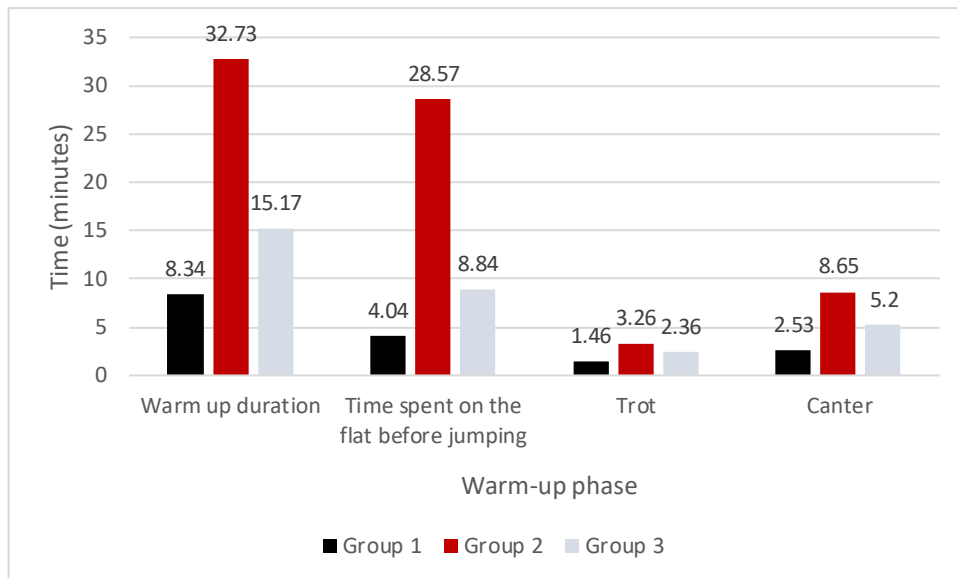
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372 Impact of competing in additional classes on warm-up regimes

373

374 The warm-up routines of Group 1 (horse and rider combinations who competed in the
375 class prior to the 1.30 m class), Group 2 (horse and rider combinations who competed
376 in a class earlier during the day) and Group 3 (horse and rider combinations who only
377 competed in the 1.30 m class) differed (Figures 7 and 8). Total warm-up duration was
378 longer for group 2 (median 32:43 minutes) than group 1 (median 8:20) and group 3
379 (15:10 minutes). Group 2 spent significantly more time warming up on the flat before
380 jumping (median 28:34 minutes) compared to Group 1 (median 4:02 minutes; $p =$
381 0.05) and Group 3 (median 8:50 minutes; $p = 0.05$). This pattern was repeated for trot
382 and canter, Group 1 ($p = 0.02$) and Group 3 ($p = 0.02$), and Group 1 ($p = 0.007$) and
383 Group 3 ($p = 0.007$) respectively. No significant differences were found for the time
384 spend in walk between the three groups ($p > 0.05$).
385

Influence of warm-up on show jumping performance



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Figure 7 : Median of warm-up duration, time spent on the flat before jumping, trot and canter for riders having jumped a previous class or not.

388

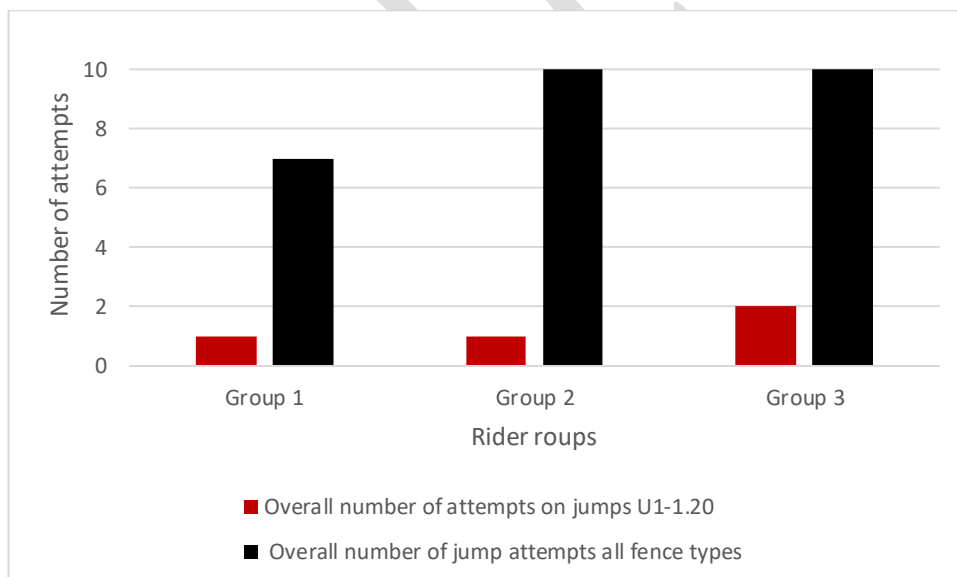
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As observed in figure 8, significant differences were also noted in the total number of jump attempts, with Group 2 and 3 recording more jump attempts than Group 1 ($p = 0.007$, increase of 42.9 %) and Group 3 had more attempts on vertical between 1-1.20 than Group 1 and 2 ($p = 0.007$, increase of 100 %).

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Figure 8 : Significant differences in jump attempts for group 1, 2 and 3

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Warm-up routine and success in the ring

401

402

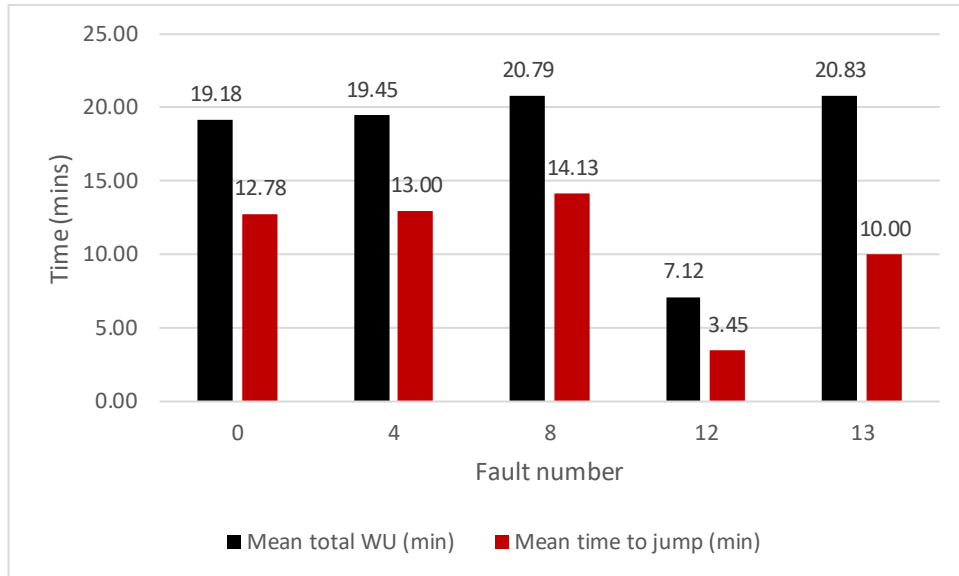
No significant differences were found between number of faults in the show ring and warm-up routines ($p > 0.05$). However as observed in figure 9, horse and rider combinations who acquired > 8 faults spent less time on the flat before jumping than competitors who recorded 8 or less faults.

405

406

Influence of warm-up on show jumping performance

407



408

409 Figure 9: Warm-up routine duration and time spent on the flat before jumping
410 compared to faults acquired in the show ring. Min: minutes

411

412 No significant correlations were found between horse age and gender or faults scored
413 and any of the variables investigated ($p > 0.05$).

414 **Discussion**

415

416 The results demonstrate that while warm-up routines varied across individual horse
417 and rider combinations, the format of the warm-up was not associated with
418 performance measured as faults accrued in competition. In human studies, an active
419 warm-up with a recovery phase has shown to increase athlete's performance when
420 done appropriately for the task to be achieved (Bishop, 2003). A high-load dynamic
421 warm-up enhances power and strength performance and it is essential to warm-up core
422 temperature to increase oxygen intake, ATP turnover, muscle glycogen availability
423 and increase motor unit recruitment (Herman, 2012; McCrary, 2014). In
424 thoroughbreds, low, moderate or high intensity warm-up does not affect performance
425 on a treadmill but affects how quickly core temperature increase and how quickly acid
426 lactic reaches threshold (Mukai, 2010). In order to increase blood temperature, heart
427 rate and lactic acid slowly and gradually, a low intensity warm-up should be used
428 (Mukai, 2010). The walk should therefore be used to stretch the horse, and ready the
429 body to work before using more dynamic gaits. Jumping also plays a key role during
430 the warm-up as rehearsal of the skills about to be performed should be practiced to
431 maximize readiness of the body, activate and recruit the muscles required (Altavilla,
432 2018; McCrary, 2014; Young, 1985).

433 Trot was the gait used the least during warm-up with standing, walking and cantering
434 duration being higher than trot. Wakeling (2007) studied the effect of walk and trot on
435 the longissimus dorsi, which is responsible for lateral bending, axial rotation and
436 extension of the spine (Haussler, 1999). This muscle is important for show jumpers as
437 lateral flexion and axial rotation of the spine occurs during a show jumping course. In
438 Wakeling's study (2007), it was discovered that more activity was created in the
439 longissimus dorsi at a trot than at a walk. Trot work also increases the horse's
440 cardiovascular input, warms up muscles symmetrically, while minimizing energy
441 expenditure, glycogen store depletion and lactic acid production (Lekeux, 1991).
442 These studies suggest that trot provides a suitable gait to facilitate aerobic warm up for
443 competition and should not be neglected.

444 During the warm-up 67% of the riders stood still for 10 secs or more. Recovery in
445 human athletes has proven to be essential, to regulate body temperature, heart and
446 respiratory rate. If a break of 15 mins is taken from the warm-up then a 2 mins active
447 re-warm-up was necessary before the main performance. The fact that riders had to
448 walk down the track to get to CR five mins before entering the show ring implemented
449 a forced break into their warm-up routine. Once in holding they had about five mins
450 for an active re-warm-up which has proven to be sufficient in human subjects (Silva,
451 2018).

452 In both humans and horses, a 15 mins warm-up has proven to increase performance
453 however in this study 49% (n=22) warm-up for shorter than 15 mins, and no significant
454 difference was found in performance (Murray, 2006; Stewart, 1998). On average,
455 riders jumped 9 fences during the warm-up, which is lower than the average of 13
456 fences observed by Tranquille (2014). The lower number here could be related to a
457 number of horse and rider combinations jumping in multiple classes, which could have
458 influenced their decision making when deciding warm-up strategies. Future research

459 to understand what factors influence rider decision making when selecting warm-up
460 tactics would be beneficial.

461

462 To restrict as much as possible the potential confounding effect of rider and horse
463 experience disrupting the data the three classes studied were of the same level (Peeters,
464 2013). However, riders and horses' experiences in the show ring as well as the extent
465 of their partnership can be limiting factors (Powers, 2005; Williams, 2013).

466

467 Rider sex did not affect horse performance in the ring, which is analogous with the
468 results found by Meyer (2008) and Wolframm (2010). However, rider sex was related
469 to differences in the warm-up routines observed. Female riders jumped less oxers than
470 male riders of a lower height (below 1m), suggesting female riders preferred a more
471 direct strategy to jump fences of increased heights during the warm-up.

472 Further research is required to understand if this result occurred by chance or reflects
473 differences in decision making aligned to rider sex. Age of the horse did not affect
474 performance in the ring, however the duration of the time spent on the flat, time spent
475 in walk and trot during the warm-up varied in relation to horse age. Anecdotally riders
476 consider older horses should walk longer during the warm-up than younger horses,
477 however in this study, we found that horses aged 14 and over spent the least time in
478 walk.

479

480 Warm-up routines were affected when a previous class was jumped prior to the 1.30m.
481 Riders who had jumped the class just before the 1.30 spent less time warming up
482 (median 8:20 minutes) compared to those who had jumped a class earlier in the day
483 classes (Median 32:43 minutes). Longer warm-up undertaken by combinations which
484 had jumped earlier in the day could be linked to Roberts et al. (2014) finding that
485 horses jumping twice on the same day had an increase in lactate level associated with
486 muscle soreness leading to a decrease in performance on the second round, however
487 in this study no detrimental impact on performance was noted. Our results suggest
488 warm-up routines in horse and rider combinations competing in 1.30m classes are
489 more variable than elite level combinations. Tranquille (2014) reported average warm-
490 up lengths of ~18 minutes in 10 elite showjumpers competing across a three-day
491 world-class training event. In class C, when no participants jumped a previous class
492 the time spent walking in the warm-up increased. However this could also be related
493 to the fact that the class was early in the morning and that the temperature was lower,
494 therefore horses may have required an increased time in walk to stretch and engage in
495 a low intensity activity to increase their body and muscle temperature prior to working
496 in collection or gymnastic jumping.

497

498

499 Limitations

500

501 Other parameters that could influence performance were not taken into account in this
502 study. These included training details, the history of the horses, potential previous time
503 off due to injury, horses' experience in the ring and at this show venue as well as
504 transport duration (Sommer, 2015; Tateo, 2012; Valera, 2012). The tack used on the
505 horses was also not assessed, ill fitted tack can create discomfort and reduce
506 performance (Clayton et al, 2013). It was noted that before jumping in the warm-up or
507 before entering the show ring, multiple riders equipped their horses with back boots,
508 which could have been weighted or pinched boots which has proven to increase

509 performance (Murphy, 2009). The effect of pre-entry and drawn order were also not
510 assessed in this study and can be considered a limiting factor on performance. Class A
511 was a class that required no previous entry and therefore no drawn order was given
512 prior to the class. On this day, standing duration was higher than on any other days.
513 Each parameter studied were not independent of each other, and age and experience
514 of the rider were not taken into account.

515
516

517 **Conclusions**

518

519 Warm-up routines varied in duration and gait used amongst riders competing in the
520 same class. Warm-up structure and knocking down or refusing a fence during the
521 warm-up did not affect the number of faults horses scored during 1.30m classes. Even
522 though there was no significant difference detected, riders who scored > 8 faults spent
523 less time on the flat before jumping during the warm-up. Rider sex influenced the
524 content of the warm-up routine observed; warranting further research to explore the
525 underlying factors which drive these differences. Horse age also influenced warm-up
526 structure, with horses aged 14 and over spending less time in walk than younger
527 horses. Jumping a class earlier in the day or just prior to the 1.30 affects warm-up
528 routine duration and content. Warm-up routines also varied for the same horse/rider
529 combinations competing in a 1.30 on different days. Trot was the gait the least used
530 for warming-up, further research would be required to understand the long-term effects
531 of such practices. The long-term effect of a short warm-up routine should be
532 investigated since prior studies have proved the positive effect on the equine
533 musculoskeletal structures which could decrease injury on a long term-basis. Further
534 research of possible factors which could affect warm-up routines and competition
535 performance such as drawn order, number of horses per rider in the class, time of the
536 day and transport is warranted.

537
538

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