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Pacing strategy and tactical positioning during cyclo-cross races

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1 **Pacing strategy and tactical positioning during cyclo-cross**
2 **races**

3

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32 **Abstract**

33 **Purpose:** To describe pacing strategy and competitive
34 behaviour in elite-level cyclo-cross races. **Methods:** Data from
35 329 men and women competing in 5 editions (2012–2016) of
36 UCI Cyclo-cross World Championships were compiled.
37 Individual mean racing speeds from each lap were normalised
38 to the mean speeds of the whole race. Lap-by-lap and final
39 rankings were also explored. Pacing strategy was compared
40 between sexes and between top- and bottom-placed cyclists.
41 **Results:** A significant main effect of laps was found in 8 out of
42 10 races (4 positive, 3 variable, 2 even and 1 negative pacing
43 strategies) and an interaction effect of ranking-based groups
44 was found in 2 (2016, male and female races). Kendall's tau-b
45 correlations revealed an increasingly positive relationship
46 between intermediate and final rankings throughout the races.
47 The number of overtakes during races decreased from start to
48 finish, as suggested by significant Friedman tests. In the first
49 lap, normalised cycling speeds were different in 3 out of 5
50 editions—men were faster in 1 and slower in 2 editions. In the
51 last lap, however, normalised cycling speeds of men were lower
52 than those of women in 4 editions. **Conclusions:** Elite
53 cyclo-cross competitors adopt slightly distinct pacing strategies
54 in each race, but positive pacing strategies are highly probable
55 in most events, with more changes in rankings during the first
56 laps. Sporadically, top- and bottom-placed groups might adopt
57 different pacing strategies during either male or female races.
58 Men and women seem to distribute their efforts differently, but
59 this effect is of small magnitude.

60
61 **Keywords:** *cyclocross; off-road cycling; pacing profile;*
62 *tactics; sex differences.*

63 Introduction

64 Cyclo-cross is a competitive discipline that demands from the
65 athletes a mix of road and off-road cycling and running
66 abilities. Races consist of many laps (~1 h in total) of a short
67 course (~3 km) comprising pavement, sand, wooded trails,
68 grass, steep hills and built obstacles. Often, the circuit requires
69 competitors to dismount, carry their bikes while running, and
70 remount. These features elicit intermittent high-intensity efforts
71 throughout the race¹. Despite being absent in the Olympic
72 Games, cyclo-cross is a popular discipline, and its World
73 Championships have been contested since 1950. However,
74 contrary to road cycling^{2,3} and mountain biking⁴, this modality
75 is virtually unexplored from a scientific point of view. As
76 suggested by Bishop⁵, sports science has not always informed
77 sports practice and descriptive work is one of the first stages
78 necessary to advance a new research field.

79
80 Among the factors underpinning endurance cycling
81 performance, pacing strategy is one of the most studied^{6,7}.
82 Descriptive⁸⁻¹⁰ and experimental¹¹⁻¹³ studies have been
83 published across disciplines, and, interestingly, a variable
84 gradient course has been considered an extra challenge to the
85 adoption of optimal pacing strategies^{6,8-10,13}. It is difficult to
86 predict, however, whether the conclusions of studies describing
87 pacing strategy in cross-country mountain bike races^{8,9} are
88 transferable to cyclo-cross—despite their resemblance in some
89 aspects such as the uneven circuits and the lap-by-lap format.
90 Abbiss et al.⁹ collected data in 2009, and, since then, race
91 duration has been reduced by ~30 min to the actual ~1.5 h. It is
92 possible that pacing strategy in the 1-h cyclo-cross could be
93 different from the ‘old’ 2-h mountain biking, due to the known
94 effect race duration exerts on intensity distribution⁶. More
95 recently, Martin et al.⁸ analysed pacing strategy during a cross-
96 country race of ~1.5 h in 6 recreationally trained cyclists
97 ($\text{VO}_{2\text{max}} = 55.1 \pm 6.0 \text{ mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$). Whether their results—an
98 even between-lap pacing strategy—reflect also the pattern of
99 elite athletes competing in cyclo-cross is unknown.

100
101 Of note, it has been shown that adjustments in racing speed are
102 more closely related to terrain gradient in running than in
103 cycling¹⁴. Since cyclo-cross involves alternations between both
104 exercise modes¹, a unique pacing profile would be
105 unsurprising, especially if the amount of running performed per
106 lap varies as the race progresses. In this regard, establishing how
107 elite athletes pace themselves during cyclo-cross races will
108 provide coaches and scientists with an in-depth understanding of
109 this discipline, generating opportunities for experimental
110 research⁵ and training interventions aiming to improved racing
111 preparation and tactics. We hypothesised cyclists generally
112 adopt a positive pacing strategy to gain a good position in the

113 first laps, with top performers adopting a more even
114 distribution than less successful competitors. The first aim of
115 this study was to test this hypothesis.

116

117 An important aspect to consider when investigating race results
118 is to separate analysis by sex. There seems to be no doubt that
119 men and women differ in exercise performance^{9,15} and inherent
120 physiology^{16,17}. Moreover, some studies in running also
121 suggest sex-based differences in pacing strategy^{18,19}. Men
122 usually slow down more than women during a race, which
123 authors attribute to distinct psychological traits, such as those
124 related to confidence and risk perception^{18,19}. Anecdotally, race
125 dynamics in cyclo-cross are greatly influenced by opponents'
126 behaviour and the need to have a clear view of obstacles,
127 potentially interfering with pacing strategy²⁰⁻²⁴. Therefore, an
128 exacerbated outcome of the aforementioned psychological
129 differences might be hypothesised—i.e. larger inter-sex
130 difference in race intensity distribution. Accordingly, the
131 second purpose of this study was to verify whether sex-based
132 differences in pacing strategy could be found among elite
133 competitors in cyclo-cross races.

134

135 **Methods**

136 **Participants and study design**

137 For this study, specific ethical approval was not sought as there
138 were no interventions and it involved the analysis of publicly
139 available data (<http://www.uci.ch>). We analysed data from elite
140 men and women competing in 5 editions (2012–2016) of the
141 UCI Cyclo-cross World Championships. Descriptive data on
142 course characteristics and weather/course conditions are
143 presented respectively in tables 1 and 2.

144

145 [Table 1]

146 [Table 2]

147

148 Initially, lap-by-lap and final times were collated for pacing
149 strategy analysis of each race. Cycling's world governing body
150 (UCI) requires timekeeping providers to adopt systems with
151 0.001-s accuracy. Mean racing speed from each lap was then
152 percentage normalised to the mean speed of the whole race for
153 each athlete. This procedure was used in order to eliminate the
154 effect of differences in absolute racing speed among cyclists
155^{7,25}. Cyclists that did not finish the entire races were excluded
156 (n = 138) and composition of the final sample (n = 329) is
157 presented in table 3. As expected, some athletes competed
158 repeatedly in different editions. However, dissimilar courses
159 and weather, together with the yearly time span between races,
160 imply individual's performance and pacing strategy were
161 always unique^{6,7,23}. Additionally, to provide a better
162 understanding of tactical arrangements and its influence on

163 pacing strategy ²²⁻²⁴, lap-by-lap and final rankings were
164 explored.

165

166 [Table 3]

167

168 Because lap number varied between male and female races and
169 among editions, data were analysed separately, totalling 10
170 individual races. The general pacing strategy of each one was
171 classified according to lap differences in exercise intensity and
172 following the descriptors utilised by Abbiss and Laursen ⁶:
173 negative, positive, even, parabolic and variable. Normalised
174 cycling speeds of the first and the last lap of each edition were
175 compared between sexes, as we expected a larger effect (if
176 present) close to the start or finish ⁶. In order to analyse the
177 effect of performance levels on pacing strategy, finishers of
178 each race were divided into two equal size groups according to
179 their final rankings—top placed and bottom placed. In the case
180 of an odd number of finishers, the bottom-placed half included
181 one more individual.

182

183 **Statistical analysis**

184 Data were assessed for normality using Shapiro-Wilk's tests and
185 subsequent analyses were chosen accordingly. To analyse
186 pacing strategies of each individual race, two-way mixed
187 ANOVAs were performed with a focus on the main effect of
188 laps and the interaction effect of ranking-based groups. Given
189 that data were previously percentage normalised, the main effect
190 of ranking-based groups would be null. Following ANOVA,
191 Bonferroni's pairwise comparisons were used to identify where
192 significant differences existed within the data. Effect sizes were
193 calculated as partial eta-squared (η_p^2). The relationship between
194 lap-by-lap and final rankings were determined by Kendall's
195 tau-b correlations ²⁶. Friedman's test was carried out to
196 investigate whether ranking changes—in absolute values—
197 would be different among laps. Finally, sex differences were
198 assessed by independent-samples *t* tests and standardised effects
199 sizes (Cohen's *d*). Data analyses were performed using SPSS
200 package (23.0, IBM, Armonk, USA) and statistical significance
201 was set at $P \leq 0.05$.

202

203 **Results**

204 Results are presented as mean \pm SD, unless otherwise stated.
205 Figure 1 displays pacing strategy adopted by top- and bottom- p
206 laced groups in each race. A significant main effect of laps was
207 found in 8 out of 10 races (2016 M: $F = 20.36$, $P < 0.001$, $\eta_p^2 =$
208 0.34 ; 2016 F: $F = 0.90$, $P = 0.411$, $\eta_p^2 = 0.02$; 2015 M: $F =$
209 17.74 , $P < 0.001$, $\eta_p^2 = 0.35$; 2015 F: $F = 5.83$, $P = 0.008$, $\eta_p^2 =$
210 0.12 ; 2014 M: $F = 21.54$, $P < 0.001$, $\eta_p^2 = 0.35$; 2014 F: $F =$
211 11.31 , $P < 0.001$, $\eta_p^2 = 0.22$; 2013 M: $F = 34.08$, $P < 0.001$, η_p^2
212 $= 0.53$; 2013 F: $F = 3.55$, $P = 0.028$, $\eta_p^2 = 0.13$; 2012 M: $F =$

213 8.22, $P < 0.001$, $\eta_p^2 = 0.27$; 2012 F: $F = 2.19$, $P = 0.074$, $\eta_p^2 =$
 214 0.07). In addition, an interaction effect of ranking-based groups
 215 was found in 2 races (2016 M: $F = 2.44$, $P = 0.049$, $\eta_p^2 = 0.05$;
 216 2016 F: $F = 11.55$, $P < 0.001$, $\eta_p^2 = 0.24$; 2015 M: $F = 1.45$, P
 217 $= 0.219$, $\eta_p^2 = 0.04$; 2015 F: $F = 1.15$, $P = 0.310$, $\eta_p^2 = 0.02$;
 218 2014 M: $F = 0.79$, $P = 0.555$, $\eta_p^2 = 0.01$; 2014 F: $F = 0.38$, $P =$
 219 0.713 , $\eta_p^2 = 0.01$; 2013 M: $F = 1.80$, $P = 0.131$, $\eta_p^2 = 0.05$;
 220 2013 F: $F = 1.48$, $P = 0.233$, $\eta_p^2 = 0.06$; 2012 M: $F = 2.12$, $P =$
 221 0.094 , $\eta_p^2 = 0.08$; 2012 F: $F = 0.77$, $P = 0.542$, $\eta_p^2 = 0.02$).
 222 Table 4 presents the mean racing time, time spent by the first
 223 and last cyclist, and general pacing strategy adopted by the
 224 whole group. Moreover, the main effect of laps is displayed and
 225 significant differences are indicated.

226

227

[Figure 1]

228

[Table 4]

229

230 Kendall's tau-b correlations revealed an increasing positive
 231 relationship (all $P < 0.001$) between intermediate and final
 232 rankings throughout the races (figure 2). Table 5 displays
 233 median ranking changes, 25th and 75th percentiles of the data.
 234 As a general trend, the number of overtakes during races
 235 decreased from start to finish, as suggested by significant
 236 Friedman tests (2016 M: $\chi^2 = 29.77$, $P < 0.001$; 2016 F: $\chi^2 =$
 237 16.89 , $P < 0.001$; 2015 M: $\chi^2 = 31.54$, $P < 0.001$; 2015 F: $\chi^2 =$
 238 16.63 , $P = 0.001$; 2014 M: $\chi^2 = 62.39$, $P < 0.001$; 2014 F: $\chi^2 =$
 239 17.40 , $P < 0.001$; 2013 M: $\chi^2 = 34.41$, $P < 0.001$; 2013 F: $\chi^2 =$
 240 11.40 , $P = 0.022$; 2012 M: $\chi^2 = 27.13$, $P = 0.001$; 2012 F: $\chi^2 =$
 241 10.25 , $P = 0.017$).

242

243 In the first lap, normalised cycling speeds were different
 244 between men and women in 3 out of 5 editions, but the fastest
 245 sex varied. Men were faster in 2013, and slower in 2014 and
 246 2012 (2016: -0.4 , $t = -0.88$, $P = 0.378$, $d = -0.02$; 2015: 1.1 , $t =$
 247 1.34 , $P = 0.185$, $d = 0.08$; 2014: -1.0 , $t = -2.31$, $P = 0.023$, $d = -$
 248 0.08 ; 2013: 1.6 , $t = 2.28$, $P = 0.027$, $d = 0.13$; 2012: -1.9 , $t = -$
 249 2.90 , $P = 0.006$, $d = -0.15$). In the last lap, however, normalised
 250 cycling speeds of men were lower than those of women in 4
 251 editions (2016: -1.8 , $t = -5.34$, $P < 0.001$, $d = -0.18$; 2015: $-$
 252 1.11 , $t = -2.38$, $P = 0.020$, $d = -0.09$; 2014: -0.8 , $t = -1.96$, $P =$
 253 0.053 , $d = -0.06$; 2013: -2.1 , $t = -3.95$, $P < 0.001$, $d = -0.15$;
 254 2012: -1.4 , $t = -2.18$, $P = 0.035$, $d = -0.10$).

255

256

[Figure 2]

257

[Table 5]

258

259 Discussion

260 This is the first study to investigate pacing strategy in cyclo-
 261 cross. As delineated by Bishop⁵, this discipline is at the stage
 262 of description of the factors that might influence performance

263 outcomes. Our findings suggest cyclo-cross competitors adopt
264 slightly distinct pacing strategies in each race, thus making it
265 difficult to attribute a single pattern to this discipline by
266 analysing lap times only. Nevertheless, a positive pacing
267 strategy was often found, especially if the first lap was not
268 considered, partially supporting our hypothesis. Moreover, top-
269 and bottom-placed groups did not differ in their pacing strategy,
270 except for the races in 2016. Finally, according to our second
271 hypothesis, men and women distributed their efforts differently,
272 an effect particularly evidenced in the last lap of races, where
273 men rode proportionally slower.

274

275 More than 20 years ago, Hansen et al.¹ had assessed race
276 demands of three elite cyclo-cross athletes competing in three
277 different races. They found cyclists typically varied their efforts
278 from zero to 800-900 W, most pedalling sequences lasted 5-20 s
279 and total running times amounted to 3, 22 and 11 min in races of
280 58, 55 and 61 min, respectively. According to Abbiss and
281 Laursen's descriptors⁶, pacing strategies in cyclo-cross are
282 variable. This is expected, due to the nature of the course that
283 does not allow for steady-state riding to occur. However, we
284 ponder that lap analyses are useful to understand exercise
285 intensity trends and the competitive behaviour on a macro scale,
286 allowing bigger sample sizes and multiple races to be
287 investigated. Given that the World Championships are the most
288 important races of the season, both in terms of points awarded
289 and prestige, we assume most athletes performed at their best.
290 We believe the findings presented here are therefore
291 generalizable to most competitions at the elite level.

292

293 In this study, we found unequivocal positive pacing strategies in
294 4 out of 10 races. Moreover, in 3 races that we classified pacing
295 strategy as variable, a positive profile would have been found
296 had the first lap been ignored. Lower speeds in the first lap do
297 not necessarily imply lower exercise intensity. Possibly, it
298 reflects congestion in the circuit, where cyclists often accelerate
299 to gain or hold a position but do not always choose the fastest
300 line²³—a classic scenario of every cyclo-cross race. This
301 suggests the first few laps are critical to race outcomes. The fact
302 we found an increasingly positive relationship between
303 intermediate and final rankings, plus the number of overtakes
304 generally decreasing from start to finish, strengthen this
305 conclusion. Interestingly, our results resemble those of cross-
306 country mountain bike races of the past (~2 h, pre-2014 UCI
307 rule change)^{9,27}. Abbiss et al.⁹ showed elite men and women
308 were faster in the second than the first lap and performance
309 declined progressively among men and maintained or declined
310 among women. Conversely, Stapelfeldt et al.²⁷ showed
311 national-level mountain bikers produced the highest power
312 outputs during the first lap of their races (also ~2 h). Taken our

313 results and those of others ^{9,27} together, we wonder whether
314 power output files from cyclo-cross races would show positive
315 pacing strategies more often than not.

316

317 Two of the cyclo-cross races in the current study were
318 categorised as having an even pacing strategy and one as a
319 negative pacing strategy. Martin et al. ⁸ also found an even
320 pacing strategy in a cross-country mountain bike race of ~1.5 h,
321 although their conclusion has been criticised ²⁸. Therefore, it is
322 difficult to explain why these pacing strategies were evident
323 based upon the descriptive data we had access to (i.e. weather
324 and course conditions, and the number of cyclists that finished
325 each race). One possibility is that the behaviour of favourite
326 cyclists may have influenced the pacing strategy of the whole
327 group of competitors ²²⁻²⁴. This is yet to be demonstrated in
328 official cyclo-cross competitions, but environment-controlled
329 studies suggest this could be a factor. Not only the presence ²⁰,
330 but also the behaviour of an opponent ²¹ affects pacing strategy,
331 especially during the initial phases of a performance trial. A
332 second possibility might be related to how often, and for how
333 long, cyclists had to run during each race ¹. As fatigue ensues,
334 cyclists tend to carry their bikes during sections otherwise
335 rideable. Given that terrain gradient exerts a bigger impact on
336 speed during running than cycling ¹⁴, it is expected that more
337 frequent and longer running sections of a course lead towards
338 positive pacing strategies, whereas sparser and shorter running
339 sections lead towards even profiles. Future studies should
340 address these hypotheses to reveal what determines the general
341 behaviour of cyclo-cross competitors.

342

343 Pacing strategy is generally recognised as a determinant of
344 cycling performance, mainly when the terrain is not entirely flat
345 ^{6,8-10,13}, which is the case of cyclo-cross. Intriguingly, our results
346 revealed that top- and bottom-placed cyclists only differed in
347 their pacing strategy during the 2016 UCI Cyclo- cross World
348 Championships. The lack of difference in most races might be
349 due to the start-order procedure that is determined as per the
350 most recent UCI athletes' classification. This system has been
351 shown to preclude major changes in rankings from the grid
352 line-up to the finish line ²⁹, a conclusion also reflected by our
353 Kendall's tau-b correlations. It is therefore conceivable that
354 top-placed cyclists led the pacing strategy of the bottom placed
355 ²²⁻²⁴, with small gaps between athletes after each lap and at the
356 finish (see table 4). In 2016, however, the best men decreased
357 their exercise intensity in the middle of the race in comparison
358 to less successful competitors, probably due to a higher-intensity
359 first lap—although not reaching statistical significance.
360 Conversely, best women started proportionally slower and
361 finished faster than less successful competitors. Conflicting
362 results were also found in a cross-country mountain

363 bike World Championships ⁹. Top-placed men maintained a
364 significantly more even pacing strategy over the race compared
365 to the bottom placed, whereas women did not display different
366 behaviours across performance groups ⁹. Unfortunately, our
367 2016 results are difficult to reconcile due to the retrospective
368 nature of our analyses.

369

370 Recent studies by Deaner et al. ^{18,19} have suggested male and
371 female athletes do not execute the same pacing strategy during a
372 race. In this regard, Deaner et al. analysed 14 running
373 marathons, adjusting women's performances by 12% to address
374 men's greater maximal oxygen uptake ¹⁸. They found women
375 often slow down less than men in the second half of races, a
376 difference they attributed to physiological aspects, decision-
377 aking characteristics, or both ¹⁸. More recently, Deaner et al.
378 tested this hypothesis by investigating the pacing strategy of
379 high-school children in 5-k cross-country running races ¹⁹,
380 where glycogen-depletion differences between sexes ¹⁷ are less
381 of a concern. Interestingly, they found similar results and
382 therefore concluded sex differences in pacing strategy are
383 probably associated to distinct psychological traits, such as
384 those related to confidence, goal orientation, risk perception, or
385 a willingness to tolerate discomfort ¹⁹. Given the distinct
386 environmental conditions and race circuits used by male and
387 female cyclists in the current study, it is not possible to attribute
388 differences between sexes to physiological or psychological
389 factors. However, our results do support the suggestion that
390 there is a difference in pacing strategy between sexes among
391 elite cyclo-cross competitors. This trend was often clearer on
392 the last lap of each race, where male cyclists rode
393 proportionally slower in 4 out of 5 editions we analysed. These
394 results must be interpreted carefully, though. Firstly, because
395 the magnitude of differences in normalised cycling speeds
396 between sexes was generally small. Secondly, because female
397 races are much shorter, and optimal pacing strategies have been
398 shown to vary according to race duration ⁶. Thirdly, because
399 our statistical analyses—comparing normalised cycling speeds
400 of the first and last laps of each edition—assume similar
401 proportions of race duration are represented, which is not
402 actually true. Thus, a prospective study design where similar
403 race durations are chosen to directly compare male and female
404 cyclo-cross athletes is preferable to confirm our results.

405

406 One further interesting finding from our study is that most
407 cyclists did not vary their exercise intensity between laps by
408 more than 5% around the mean race speed, regardless of the
409 race considered. This was even more remarkable as each lap
410 represented between 10 and 25% of the total distance,
411 depending on the race edition. This lack of pacing variability is
412 in stark contrast to laboratory-based studies where pacing

413 strategy has been experimentally manipulated to investigate its
414 impact on performance. For example, Mattern et al.¹²
415 manipulated power output by 15% below and above the mean
416 of the first 4 min of a ~32.6-min self-paced time-trial (which
417 case 4 min represented ~12.2% of the completion time). They
418 showed well-trained cyclists failed to select an optimal start
419 strategy during a 20-km time-trial, with 10 out of 13
420 participants recording their fastest times during the lower-
421 intensity starting condition. Moreover, using an observational
422 study design, Thomas et al.¹¹ demonstrated cyclists adopted a
423 fast-start strategy during a 20-km time-trial (~32.5 min), with
424 the first 30% completed 4-10% above the mean power output;
425 the next 60%, 1-7% below the mean power output; and the last
426 10%, 6% above the mean power output. Therefore, it is fair to
427 say that elite cyclo-cross competitors have been performing
428 their pacing strategies well^{22,23}. Despite the stochastic nature of
429 this discipline¹, meaning each lap needs to be negotiated
430 according with the demands of the rolling circuit¹³ and in
431 response to other competitors²²⁻²⁴, they are still able to
432 maintain a lap-by-lap scheme in perspective, with low
433 variability in their lap times. It could be argued, then, that
434 cyclists adopted an even pacing strategy. Indeed, the practical
435 significance of minor between-lap differences needs to be
436 further explored. Nonetheless, our statistical classification
437 suggests that, although of small magnitude, the (mostly positive)
438 patterns we found did not happen by chance.

439
440 This study is not without limitations. As mentioned previously,
441 power output files could provide insights beyond those offered
442 here by analysing lap-by-lap performances, particularly the
443 influence of cycling-running transitions on pacing strategy and
444 performance. In addition, descriptive research is only a starting
445 point in the process of implementing performance solutions, and
446 studies with a more controlled environment are also needed^{5,23}

447 . Finally, establishing the veracity of a large dataset is
448 always a concern³⁰. However, we are confident that if errors
449 exist, they are minor, as we acquired information directly from
450 UCI.

451

452 **Practical Applications**

453 Our findings are likely to be used by athletes and coaches when
454 developing optimal pacing strategies for cyclo-cross races.
455 Cyclists aiming to reach the highest levels of this discipline
456 must be aware that a powerful start and good positioning
457 abilities are required to be among the best competitors, given
458 that lap times are generally faster in the first laps. Moreover, we
459 propose that strong efforts (i.e. to overtake opponents and to
460 overcome steep ascents and running sections) must be well
461 paced and performed throughout a race, as large (> 5%)
462 deviations in mean speed of each lap are probably detrimental

463 to overall performance. In addition, the decision-aking process
464 involved in choosing the right actions during a race is probably
465 important to warrant a pacing strategy close to optimal^{23,24}.
466 Therefore, training programmes cannot ignore this component.

467

468 **Conclusion**

469 In summary, this study shows elite cyclo-cross competitors
470 adopt slightly distinct pacing strategies in each race, but positive
471 pacing strategies are highly probable in most events. Our results
472 also suggest that, sporadically, top- and bottom- placed cyclists
473 might adopt different pacing strategies during either male or
474 female races. Finally, male and female cyclo- cross athletes
475 seem to distribute their efforts differently, but this effect is of
476 small magnitude, likely reflecting the shorter races of the female
477 category.

478

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488

489 **References**

490

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609 **Table & Figure Captions**

610

611 **Table 1** – Course distance, number of laps for each race,
612 altitude of the host city, elevation difference between the
613 highest and lowest point of the circuit, elevation gain per lap
614 and maximum gradient along the course.

615

616 **Table 2** – Start time, weather and course conditions during
617 each race.

618

619 **Table 3** – Study's sample (Finishers; $n = 329$) and excluded
620 individuals (LAP/DNF/DNS/DSQ; $n = 138$).

621

622 **Table 4** – Total racing time, general pacing strategy and laps
623 where normalised cycling speeds were statistically different.

624

625 **Table 5** – Absolute ranking changes among all competitors per
626 lap of each race.

627

628 **Figure 1** – Pacing strategy adopted by top- (filled circles) and
629 bottom-placed (open circles) groups in each race. M: males; F:
630 females; *: significant main effect of laps; §: significant
631 difference between groups at the point (simple effects).

632

633 **Figure 2** – Kendall's tau-b correlations between intermediate
634 and final rankings of each individual race (all $P < 0.001$).

635

636

637

Table 1 – Course distance, number of laps for each race, altitude of the host city, elevation difference between the highest and lowest point of the circuit, elevation gain per lap and maximum gradient along the course.

Year	Host City	Course Distance (km)	Laps	Altitude (m)	Elevation Difference (m)	Elevation Gain (m)	Maximum Gradient (%)
2016	Heusden-Zolder (Belgium)	3.27	M: 8 / F: 4	43	19	59	24.7
2015	Tábor (Czech Republic)	3.13	M: 8 / F: 5	437	23	48	28.3
2014	Hoogerheide (Netherlands)	3.36	M: 8 / F: 4	11	17	50	12
2013	Louisville (USA)	2.79	M: 9 / F: 6	142	8	25	45.9
2012	Koksijde (Belgium)	2.94	M: 10 / F: 5	1.5	14	25	30.8

M: males; F: females.

Table 2 – Start time, weather and course conditions during each race.

Race	Start Time	Precipitation	Atmospherics	Course Conditions	Temperature (°C)	Humidity (%)	Wind (km/h)
2016 M	3:00 pm	Rain	Overcast	Slick/Claggy Mud	6	93	15
2016 F	3:00 pm	Rain	Overcast	Wet/Slippy Mud	7	86	20
2015 M	2:00 pm	Snow	Overcast	Slippy Mud/Ice	1	84	10
2015 F	2:00 pm	None	Overcast	Slippy Mud/Ice	0	83	6
2014 M	3:00 pm	None	Sunny	Claggy Mud	8	78	16
2014 F	3:00 pm	None	Overcast	Claggy Mud	8	85	18
2013 M	2:30 pm	Snow	Overcast	Slippy Mud/Ice	0	88	21
2013 F	11:00 am	Snow	Overcast	Slippy Mud/Ice	-3	95	18
2012 M	3:00 pm	None	Overcast	Sand/Slippy Mud	3	72	14
2012 F	11:00 am	None	Overcast	Sand/Slippy Mud	2	83	11

M: males; F: females.

Table 3 – Study's sample (Finishers; n = 329) and excluded individuals (LAP/DNF/DNS/DSQ; n = 138).

Race	Finishers	LAP/DNF/ DNS/DSQ
2016 M	41	20
2016 F	38	1
2015 M	35	25
2015 F	44	2
2014 M	42	19
2014 F	41	3
2013 M	32	13
2013 F	25	7
2012 M	24	40
2012 F	31	8

M: males; F: females; LAP: lapped; DNF: did not finish; DNS: did not start; DSQ: disqualified.

Table 4 – Total racing time, general pacing strategy and laps where normalised cycling speeds were statistically different.

Race	Total Time mean (range)	General Pacing Strategy*	Lap Differences $P \leq 0.05$
2016 M	1:09:24 (1:05:52 – 1:13:31)	Variable	1 ≠ 2, 8; 2 ≠ 4, 5, 6, 7, 8; 3 ≠ 4, 5, 6, 7, 8; 4 ≠ 7, 8; 5 ≠ 8; 6 ≠ 7, 8; 7 ≠ 8
2016 F	0:44:43 (0:41:03 – 0:51:48)	Even	N/A
2015 M	1:12:55 (1:09:12 – 1:17:05)	Positive	1 ≠ 8; 2 ≠ 5, 6, 7, 8; 3 ≠ 6, 7, 8; 4 ≠ 6, 7, 8; 5 ≠ 7, 8; 6 ≠ 7, 8
2015 F	0:53:03 (0:49:10 – 0:58:15)	Positive	2 ≠ 4, 5; 3 ≠ 4, 5
2014 M	1:09:07 (1:05:29 – 1:12:31)	Variable	1 ≠ 2, 7, 8; 2 ≠ 3, 4, 5, 6, 7, 8; 3 ≠ 5, 6, 7, 8; 4 ≠ 6, 7, 8
2014 F	0:43:57 (0:39:25 – 0:49:34)	Positive	1 ≠ 3, 4; 2 ≠ 3
2013 M	1:08:31 (1:05:35 – 1:11:35)	Variable	1 ≠ 2, 6, 7, 8, 9; 2 ≠ 4, 5, 6, 7, 8, 9; 3 ≠ 5, 6, 7, 8, 9; 4 ≠ 5, 6, 7, 8, 9; 5 ≠ 8, 9; 7 ≠ 8, 9
2013 F	0:46:40 (0:43:00 – 0:49:36)	Positive	2 ≠ 5, 6; 3 ≠ 6
2012 M	1:08:51 (1:06:07 – 1:11:17)	Negative	1 ≠ 3, 4, 5, 6, 7, 8
2012 F	0:44:26 (0:41:04 – 0:47:59)	Even	N/A

M: males; F: females; *: general behaviour according to Abbiss and Laursen's descriptors⁶; $P \leq 0.05$: significant differences found following Bonferroni pairwise comparisons; N/A: not applicable.

Table 5 – Absolute ranking changes among all competitors per lap of each race.

Race	Ranking Changes median [Q ₁ – Q ₃]								
	Laps 1 – 2	Laps 2 – 3	Laps 3 – 4	Laps 4 – 5	Laps 5 – 6	Laps 6 – 7	Laps 7 – 8	Laps 8 – 9	Laps 9 – 10
2016 M	2 [1 – 4]	1 [0 – 2]	1 [1 – 2]	1 [0 – 2]	1 [0 – 2]	1 [0 – 1.5]	0 [0 – 1]		
2016 F	1 [0 – 2.25]	1 [0 – 1]	0 [0 – 1]						
2015 M	2 [1 – 4]	1 [0 – 3]	1 [0 – 3]	1 [1 – 2]	1 [1 – 2]	0 [0 – 1]	1 [0 – 2]		
2015 F	2 [1 – 3]	2 [1 – 3]	1 [0 – 2]	1 [0 – 2]					
2014 M	3 [1.75 – 6]	1.5 [1 – 3]	1 [1 – 2]	1 [0 – 2]	1 [0.75 – 2]	1 [0 – 1.25]	0.5 [0 – 1.25]		
2014 F	2 [1 – 5]	1 [1 – 3]	0 [0 – 1]						
2013 M	2 [1.25 – 3]	1 [1 – 3]	1 [0 – 2]	1 [0 – 2]	1 [1 – 1.75]	1 [0 – 2]	1 [0 – 2]	0.5 [0 – 1]	
2013 F	1 [0 – 2]	1 [0 – 2]	1 [0 – 1]	1 [0 – 2]	0 [0 – 1]				
2012 M	2 [1 – 5.75]	1 [0 – 2]	1 [0 – 2]	1 [0 – 2.75]	0.5 [0 – 2]	1 [0 – 1.75]	1 [0 – 1]	1 [0 – 2]	0.5 [0 – 1]
2012 F	1 [1 – 3]	1 [0 – 2]	1 [0 – 2]	1 [0 – 1]					

M: males; F: females; Q₁: 25th percentile; Q₃: 75th percentile.

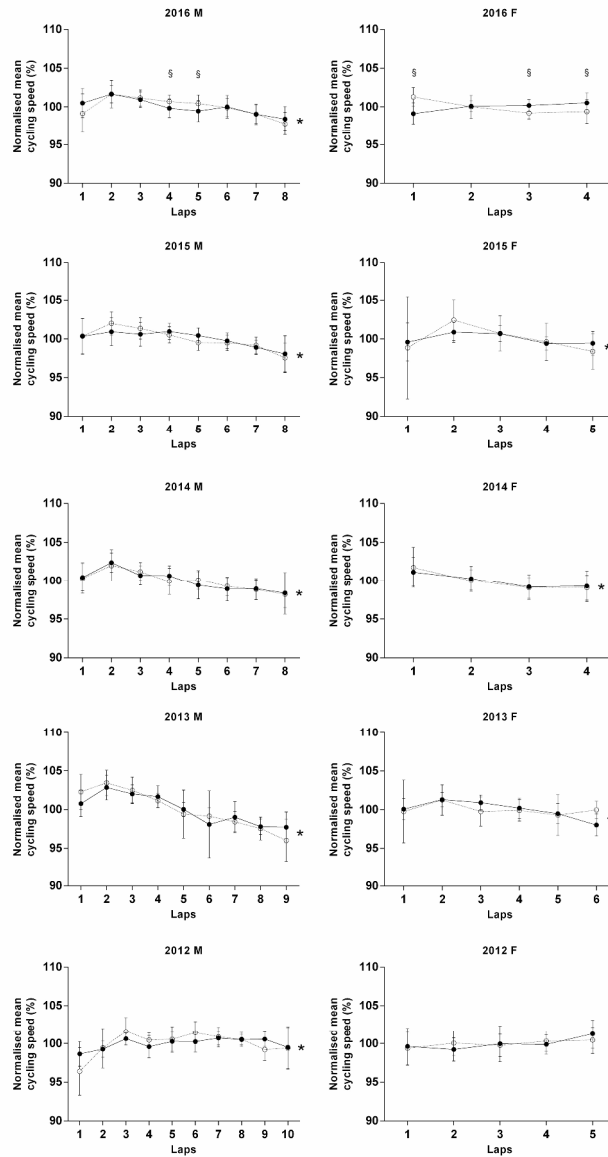


Figure 1 – Pacing strategy adopted by best- (filled circles) and worst-ranked (open circles) groups in each race. M: males; F: females; *: significant main effect of laps; §: significant difference between groups at the point (simple effects).

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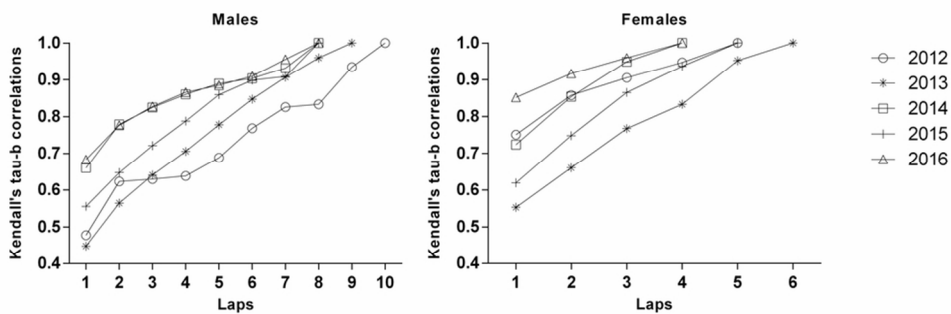


Figure 2 – Kendall's tau-b correlations between intermediate and final rankings of each individual race (all P < 0.001).

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