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Original Article

Pacing Profile and Performance of Under 23 and Elite Mountain Bikers During Cross-Country Short Track Event

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Abstract: The aim of this study was to investigate the distribution of speed and performance of professional cross-country cyclists on different technical and non-technical sections during a cross-country short track (XCC) mountain biking (MTB) event. Twenty male professional cross-country cyclists (25.9 ± 5.4 years) performed six laps of an XCC International Mountain Bike Cup. In addition to categories [Under 23 (n = 8) and Elite (n = 12)], cyclists were divided into three groups according to their overall race completion time, being categorized as top (n = 6), middle (n = 8) and bottom (n = 6) placed finishers (race time groups). Average speed (by lap and in five different track sections) was analyzed according to all athletes, categories and race time group. Athletes in general and both categories adopted a positive pacing. Top cyclists adopted a "W-shaped" pacing, while middle and bottom cyclists adopted a positive and parabolic-shaped pacing profile, respectively. Regarding track sections performance, no difference was found between categories ($p > 0.05$). Nevertheless, top cyclists were 18.8% ($p < 0.05$), 6.7% ($p < 0.05$) and 4.1% ($p < 0.05$) faster than bottom cyclists on sustained non-technical uphill, technical short uphill/downhill section and non-technical downhill sections of the track, respectively. The results show that majority of athletes adopted a positive pacing profile for the analyzed circuit, but the better XCC performance was associated with a "W-shaped" pacing profile and higher performance mainly on sustained non-technical uphill.

Keywords: speed, race pace, off-road cycling, MTB, cycling.

1. Introduction

Cross-country short track (XCC) is a mass-start mountain biking (MTB) event, performed on a closed-loop with a distance not exceeding 2 km (Union Cycliste Internationale [UCI] regulations, Part 4 mountain bike, version from 05 may 2023). This event lasts between 20-30 minutes and includes repeated uphill and downhill sections performed over a diverse range of terrains including forest tracks, earth or gravel paths (UCI regulations, Part 4 mountain bike, version from 05 may 2023). Despite Cross-Country Olympic (XCO) being the most popular MTB event, XCC has gained attention in recent years. Indeed, in the year 2021, a world XCC championship was developed, and race results are likely to influence the starting position of some XCO events and UCI world rankings. However, it is not still know how mountain bikers respond on XCC event.

Previous researchers have analyzed critical factors that influence MTB cycling performance, such as pacing behavior and performance on different sections of the course over the race (Arriel, Souza, Sasaki, & Marocolo, 2022). Pacing is generally defined as the control of speed (or effort/energy expenditure) throughout an exercise task and, it is well recognized as a critical factor that dictates performance within competition (Abbiss & Laursen, 2008; St Clair Gibson et al., 2006). It has been suggested that pacing regulation occurs through the complex relationship between brain and other physiological systems (St Clair Gibson et al., 2006). It means that information received by the brain, via afferent sensorial feedback from physiological systems, are identified, interpreted and then, an appropriate neural command is generated to reach an ideal speed over the race. However, pacing during head-to-head competition is further complicated, maybe due to numerous external factors, such as different behavior opponents (Konings & Hettinga, 2018). Moreover, the particular pacing profile adopted by cyclists during competition differ among genders, ages and athlete performance level (Abbiss et al., 2013; Moss, Francis, Calogiuri, & Highton, 2019). While significant research exists outlining optimal pacing strategies during discrete, stable, closed-loop exercise tasks (Konings & Hettinga, 2018), the pacing profile adopted during XCC is more complex and less understood.

A high degree of technical ability is required to succeed in MTB due to the variety of terrains including up- and downhill, drops and obstacles (Arriel et al., 2022). Therefore, in addition to pacing profile, previous researchers have investigated the performance of mountain bikers, with different overall race completion times, on technical and non-technical up- and downhill sections in XCO (Abbiss et al., 2013) and cross-country marathon events (XCM) (Moss et al., 2019). During an XCO competition, top placed finishers were faster than lower placed finishers on technical uphill section of the course, while in the XCM this difference was found on section composed by short climbs and descents. This analysis is important because could explain, at least in part, the overall performance differences among top, middle and bottom placed finishers. However, this has not been examined in the XCC. In this context, the aims of this study were to investigate pacing profile adopted by professional cross-country cyclists and assess their performance through of speed (or time spent) on technical and non-technical up- and downhill sections along the laps during an official XCC competition, examining whether there is influence of category and performance level on these parameters. We hypothesized that the majority of the athletes would adopt a positive pacing, but the top placed finishers would adopt a more even pacing and would be faster than bottom placed finishers on non-technical uphill section of the course.

2. Materials and Methods

2.1. Subjects

The performance of twenty male professional cross-country cyclists [25.9 ± 5.4 yrs; range: 19 – 39 yrs; categories: eight Under 23 (U23) and twelve Elite] was assessed within this study. The two higher time gaps between two cyclists were used as a cutoff for dividing athletes into three groups, then categorized as top (first fastest cyclists; n = 6; 24.5 ± 3.8 yrs; range: 19 - 30 yrs), middle (second fastest cyclists; n = 8; 27.6 ± 6.6 yrs; range: 20 - 39 yrs) and bottom placed finishers (third fastest cyclists; n = 6; 25.0 ± 5.0 yrs; range: 20 - 32 yrs) (Abbiss et al., 2013). All cyclists were registered by the local cycling confederation and had experience in at least one national and/or international competition (i.e., National championship, MTB International Cup and MTB World Cup). Previous results showed that sixteen of the athletes finished at the least once in the top 20 and four in the top 10 positions in one of above competitions. This study was performed in accordance with the Declaration of Helsinki, and approved by the local ethical committee for human experiments (n. 4.120.625).

2.2. XCC competition and track course profile

XCC competition was performed during the 2020 UCI International Mountain Bike Cup, involving six laps on a closed-loop. All cyclists of both U23 and elite categories performed the XCC at the same time. Total distance cycled per lap (2.3 km), total elevation gain (280 m), altitude (998 m), temperature (24.8 ± 1.4 ºC) and average speed of the wind (24.5 km/h) were measured and provided by event organization (http://cimtb.com.br). The XCC track comprised a combination of 5% of tarmac, 10% of cobblestones and 85% of dirt-track composed of uphill, downhill and flat, but with less single tracks, obstacles (rock gardens, tree roots and mud), narrow turns and technical sections when compared with other MTB competitions (Abbiss et al., 2013; Moss et al., 2019). We decided to separate the XCC track course into five sections according to topography (uphill, downhill and flat), technical and non-technical sections to assess the performance in each section along the laps during XCC competition. To be considered technical, the section should be composed by natural or artificial obstacle such as rock gardens, drops, tree roots, very tight curve or single track. Otherwise, the section was classified as non-technical. These technical sections were assessed and classified by the researcher involved in this study, following the UCI cycling regulations (UCI regulations, Part 4 mountain bike, version from 05 may 2023). We have also assessed the performance, through of speed and/or time spent, of both elite and U23 category and of the three groups of riders on each section. Figure 1 shows the XCC course profile and characteristics of each section.

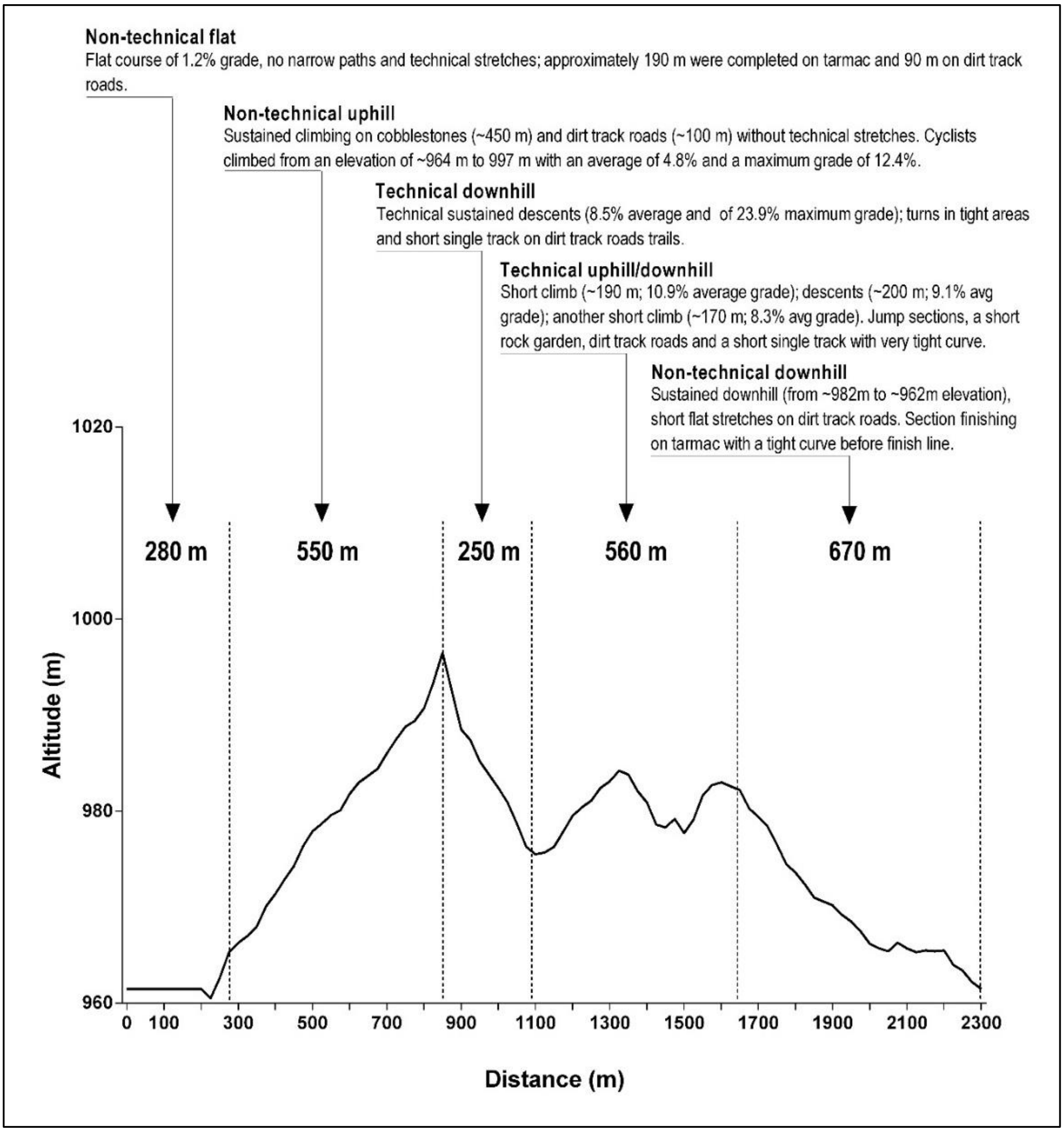

Figure 1. Cross-country short track (XCC) course profile, location and characteristics of each track section for an individual lap.

2.3. Data collection

Total time, distance and speed over entire race were recorded through of individual devices (Garmin® Edge, Kansas City, United States; Polar®, Finland; and Bryton Rider®, Taipei, Taiwan), which posteriorly were downloaded for each cyclist directly in the Strava® program. Strava is a mobile app for helping athletes in controlling training session and season, which they can record and share their own race or training data with the public. Therefore, the data were of public domain, and only publicly accessible sources were used. All data were downloaded from Strava and analyzed by two independent reviewers. Based on the Abbiss et al. (2013) study, we correlated total race time recorded by individual devices with the time recorded by the official system of the International Mountain Bike Cup, which was classified as nearly perfect ($r = 0.999$, $p < 0.01$) (Mukaka, 2012). To analyze pacing profile, we examined average speed lap by lap, and to analyze pace across the five sections, we examined average speed of the section in each lap. The coefficient of variation (CV) of speed across laps was determined using standard deviation (SD) divided by average speed (AS) multiplied by 100 [i.e. CV = (SD/AS)*100].

2.4. Statistical analysis

IBM SPSS (Version 23) and GraphPad (PRISM®, 6.0, San Diego, USA) statistical program were used for performing the data analyses. Shapiro-Wilk test was used for checked the normality of the data. To compare total time, average speed, CV of speed across laps of the race and of each track section between categories and among race time groups, an independent Student t-test (or Mann-Whitney test) and a one-way analysis of variance (ANOVA) (or Kruskal-Wallis test) were used, respectively. Considering all athletes, a separate one-way ANOVA for repeated measures (or Friedman test) was conducted for analyzing average speed across the laps of the race. In addition, the same test was used to compare the average speed of the track section in each lap. Two-way ANOVA mixed model was conducted for each independent variable (categories and race time group) to analyze within and among groups the average speed across laps during XCC. When necessary, a Bonferroni's *post-hoc* test was employed. The level significance adopted was $p < 0.05$.

3. Results

3.1. All athletes

All athletes performed the XCC race with a total distance of 13.8 km and duration of 38 ± 1 min without known injury or mechanical delays. The mean time of participants of this study was about 6.3% (range: 1.7 – 12.2 %) greater than the winner's overall race time to complete this XCC competition (the top one of 2020 World rank). Average race speed was of 21.7 ± 0.7 km/h with CV of speed across laps of 2.8 ± 1.1% (Table 1). During competition, average speed was similar between lap 1 and lap 2, decreased from the lap 2 to lap 3, and it was similar from the lap 3 until lap 6 (Figure 2A).

Cyclists were significantly faster on non-technical flat and slowest on technical uphill/downhill section. CV of speed across laps for each section was greatest in non-technical flat and lowest in non-technical downhill (Table 2). The Figure 2B shows the average speed of each track section in each lap. In the non-technical flat section, speed decreased over the laps. In the non-technical uphill section, after lap 1 and lap 2, speed decreased in lap 3 and was maintained from the lap 3 until lap 6. In technical downhill section, speed increased from lap 1 to lap 2, which was maintained until lap 6. In technical uphill/downhill section, no difference in speed was found among laps ($p = 0.09$). Lastly, in non-technical downhill section, speed was maintained from lap 1 until lap 3, significantly decreased in lap 4 and lap 5 compared with lap 1, and it increased from the lap 5 for lap 6.

Table 1. Total time, average speed and coefficient of variation (CV) of speed across laps of the cyclists according to general, categories and race time groups in overall race.

	Total Time (min)	Speed (km/h)	CV (%)
General			
All athletes	38 ± 1.3	21.7 ± 0.7	2.8 ± 1.1
Categories			
U23	39 ± 1.4	21.5 ± 0.8	3.2 ± 1.1
Elite	38 ± 1.2	21.8 ± 0.7	2.5 ± 1.0
Race time groups			
Top	37 ± 0.1[a,b]	22.6 ± 0.1[a,b]	2.2 ± 0.6
Middle	38 ± 0.5[b]	21.7 ± 0.3[b]	3.3 ± 0.9
Bottom	40 ± 0.3	20.8 ± 0.2	2.7 ± 1.4

Data are mean ± SD.

a. $p < 0.05$ compared with middle; b. $p < 0.05$ compared with bottom.

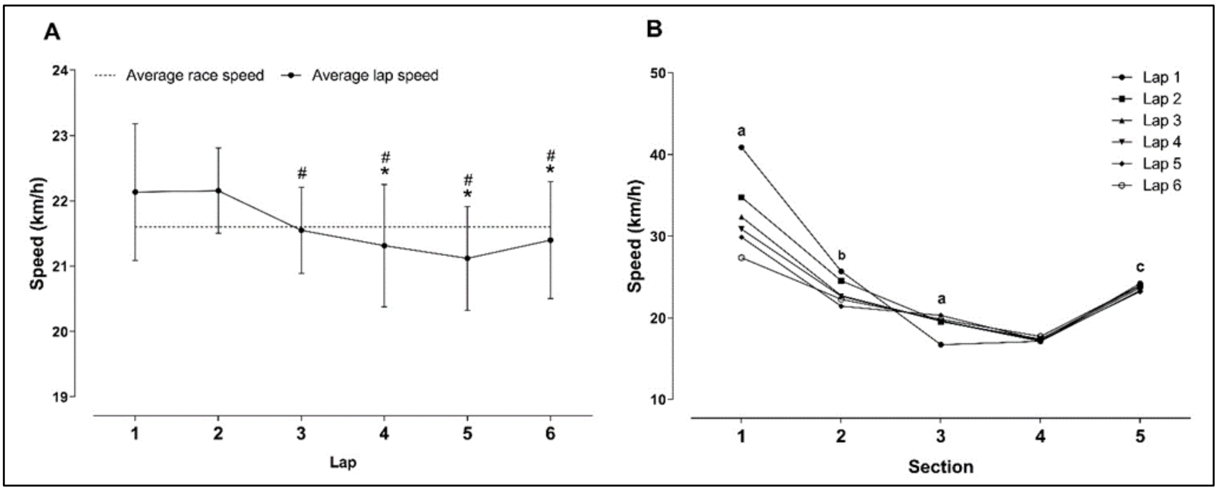

Figure 2. Pacing profile (A) and average speed of each section in each lap (B) according to all cyclists over the entire XCC competition. Data are expressed as mean ± SD in A and as mean in B.
* $p < 0.05$ compared with lap 1; # $p < 0.05$ compared with lap 2; a $p < 0.05$ = lap 1 compared with all other laps within same section; b $p < 0.05$ = lap 1 compared with lap 3 to 6 within same section; c $p < 0.05$ = lap 1 compared with lap 4 and 5 within same section.

Table 2. Average speed and coefficient of variation of speed (CV) across laps of cyclists according to general, categories and race time groups in each track section.

	Non-technical flat			Non-technical uphill			Technical Downhill			Technical Uphill/Downhill			Non-technical downhill		
	Time (s)	Speed (km/h)	CV (%)	Time (s)	Speed (km/h)	CV (%)	Time (s)	Speed (km/h)	CV (%)	Time (s)	Speed (km/h)	CV (%)	Time (s)	Speed (km/h)	CV (%)
General															
All athletes	31.5	32.1	15.5	86.5	23.1	8.7	47.4	19.1	10.1	116.7	17.3	3.8	101.8	23.7	2.6
Categories															
U23	31.7	31.8	15.0	87.5	22.8	9.9	46.9	19.2	9.2	118.8	17.0	3.2	102.0	23.7	3.0
Elite	31.4	32.3	15.8	85.8	23.2	7.9	47.7	18.9	10.7	115.3	17.5	4.1	101.7	23.7	2.3
Race time groups															
Top	31.6	32.0	16.7	77.5[a,b]	25.6[a,b]	6.5	46.7	19.3	8.1	112.8[b]	17.9[b]	3.3	99.8[b]	24.2[b]	2.3
Middle	30.8	32.8	15.5	86.7[b]	22.9[b]	9.1	47.9	18.8	10.2	116.6	17.3	4.3	101.5	23.8	3.0
Bottom	32.3	31.2	14.3	95.2	20.8	10.1	47.3	19.1	11.9	120.7	16.7	3.5	104.3	23.2	2.4

Data are mean.

Comparison within the same track section: a $p < 0.05$ compared with middle; b $p < 0.05$ compared with bottom.

3.2. U23 and elite

Total time, average speed and CV of speed across laps of the race were similar between U23 and elite categories (Table 1). Pacing profile adopted during the XCC competition by both categories was also similar. They maintained a similar speed in lap 1 and lap 2, but decreased in lap 3. After this reduction, cyclists of both categories were able to maintain a similar speed until lap 6. This information is displayed in Figure 3.

Both U23 and elite were faster on non-technical flat section and slower on technical uphill/downhill section, and they presented a higher CV of speed across laps on non-technical flat section and a lower on non-technical downhill section. No significant difference was found for average speed and CV of speed across laps in each circuit section between categories (Table 2).

3.3. Race time

As expected, total race time and average race speed were significantly different among race time groups. Average race speed was significantly higher in top cyclists group, and sequentially decreased for each slower group. Total race time was lower in top cyclists group, and sequentially increased for each slower group. No significant change in CV of speed across laps was found among groups (Table 1). However, top cyclists showed a "W-shaped" pacing over the race, while middle adopted a positive pacing and bottom a parabolic-shaped pacing profile (Figure 4).

In all laps top placed cyclists were significantly faster than bottom placed, while middle performs were significantly faster than bottom performs in lap 1, lap 2, lap 4 and lap 5 (Figure 4).

During race, all race time groups were faster on non-technical flat and slower on technical uphill/downhill section, and they presented a higher CV of speed across laps on non-technical flat section and a lower on non-technical downhill section of the XCC track course. Considering average speed, top cyclists were, respectively, 10,5% and 18.8% faster than middle and bottom performs on non-technical uphill section, 6.7% faster than bottom performs on technical uphill/downhill section, and 4.1% faster than bottom cyclists on non-technical downhill section (Table 2).

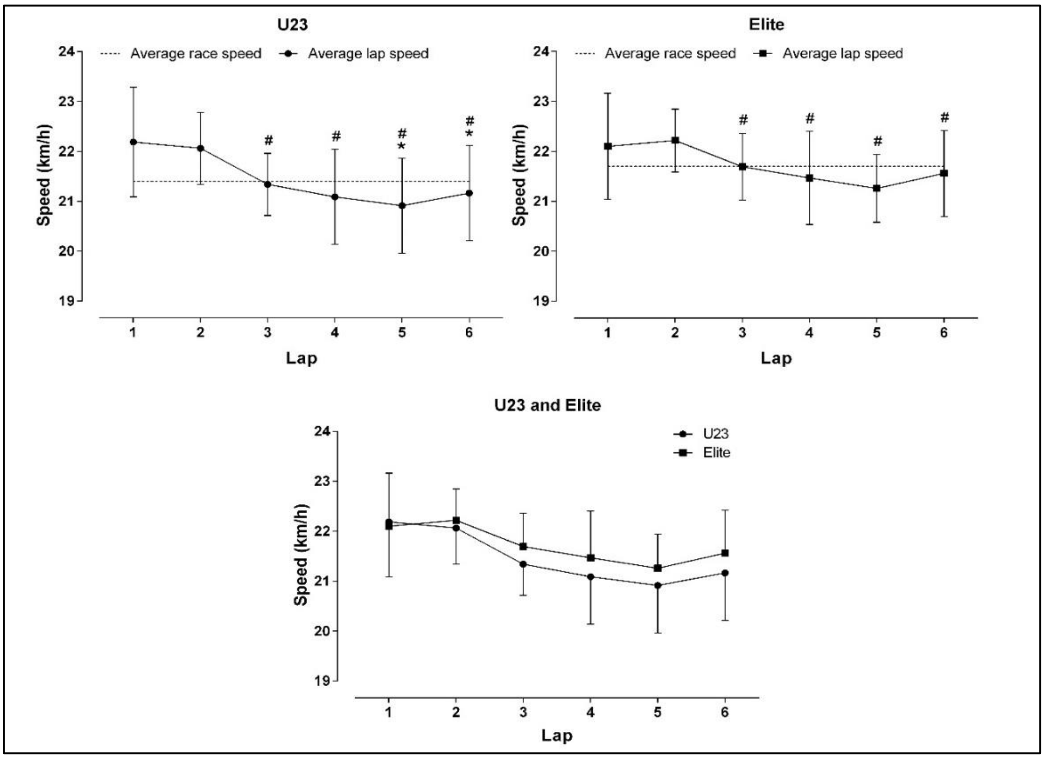

Figure 3. Pacing profile according to U23 and elite categories over the entire XCC competition. Data are expressed as mean ± SD.* $p < 0.05$ compared with lap 1; # $p < 0.05$ compared with lap 2.

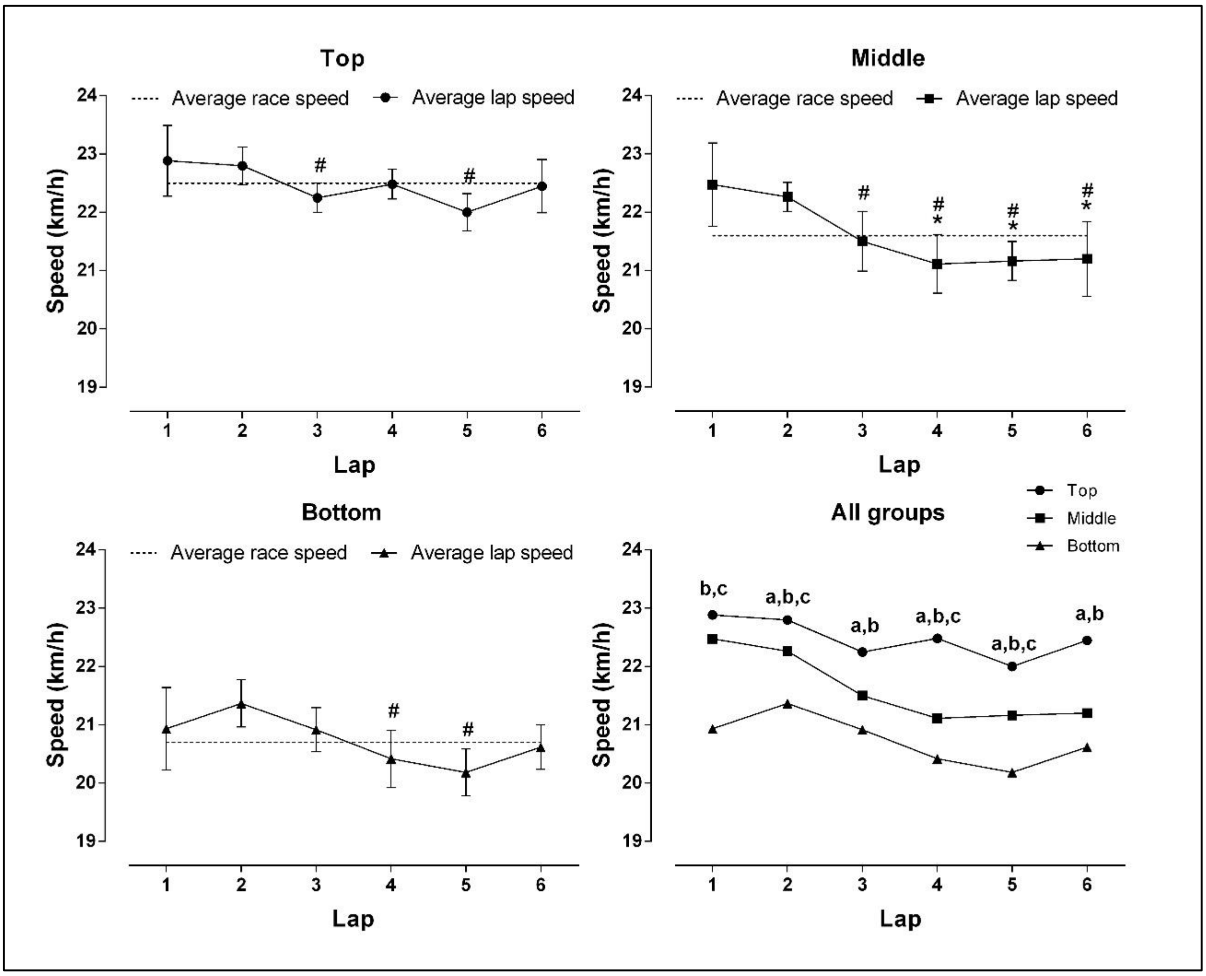

Figure 4. Pacing profile according to race time group over the entire XCC competition. Data are expressed as mean ± SD in top, middle and bottom, and as mean in all groups.
* $p < 0.05$ compared with lap 1; # $p < 0.05$ compared with lap 2; Comparison within the same lap: a $p < 0.05$ = top compared with middle placed finishers; b $p < 0.05$ = top compared with bottom placed finishers; c $p < 0.05$ = middle compared with bottom placed finishers.

4. Discussion

The purpose of this study was to investigate the pacing profile adopted by professional cross-country cyclists and assess their speed and/or time spent on technical and non-technical uphill and downhill sections during an XCC competition, examining if there is influence of the categories and performance level on these parameters. Our main finding was that, regardless of category, cyclists adopted a positive pacing profile. However, faster cyclists adopted a "W-shaped" pacing profile (i.e. when there is a decrease followed by an increase in speed observed twice over the duration of the event), reporting higher speed (or lower time spent) during some sections of the track, mainly on sustained non-technical climbing.

Previous researchers have analyzed important factors that may influence MTB cycling performance (Arriel et al., 2020), including pacing profile in XCO (Abbiss et al., 2013) and XCM (Moss et al., 2019). However, this is the first study to analyze the pacing profile during an official XCC competition. When the study was carried out the XCC race duration recommended by the UCI was of 20 to 60 minutes, which is in line with our value (38 ± 2 min) (Part 4 mountain bike, version from February 2020). However, UCI recommendations was updated in 2023, altering race time to 20-30 min (UCI regulations, Part 4 mountain bike, version from 05 may 2023). Average race speed was of 21.6 ± 0.7 km/h, which indicate that this specific XCC competition was 9.7% faster than XCO competition (19.7 ± 2.1 km/h considering 13 international races) (Granier et al., 2018).

During XCC race, after faster first and second lap, cyclists significantly reduced speed followed by an even pacing until the end of the competition, which is representative of a positive pacing (Figure 2A). Both U23 and elite cyclists also adopted a positive pacing, showing that this parameter is not influenced by category level (U23 and Elite) (Figure 3), which is in line with previous study in MTB (Abbiss et al., 2013). The regulation of pacing has been attributed to the relationship between a brain algorithm, which was created through knowledge of the endpoint and memory of previous similar events, and other physiological system (St Clair Gibson et al., 2006; Ulmer, 1996). That is, through afferent sensorial feedback from other physiological systems (e.g., cardiovascular, muscular, respiratory…), together with data from the external conditions (as environmental), the brain algorithm calculates whether the athlete's speed (or power output) is appropriate to reach the end of the exercise at the shortest time possible without inducing premature fatigue, which impairs overall performance. In this hand, we can speculate that this large acceleration of the cyclists at the beginning of the XCC race was interpreted by brain algorithm as unsustainable until the end of the race, leading the cyclists to a reduction in speed after the second lap. Nevertheless, it is relevant to highlight that during mass-start event, as in XCC and XCO competitions, athletes tend to adopt an aggressive race start (Granier et al., 2018) in order to place themselves in the front positions to benefit from riding solo, avoiding congestion and crashes in sections composed of single track and turns in tight areas, which could impair their overall performance. Indeed, across the laps we observed that athletes were faster on non-technical flat and slower on technical downhill (section consisting of a single track) in the first lap (Figure 2B), showing that cyclists really adopted an aggressive race start and probably experienced a congestion and/or crashes. After the second lap, cyclists reduced speed either because placed themselves in better positions or because of the dynamics of the competition at that time. Previous MTB studies evaluating pacing profile in XCO competition support this (Abbiss et al., 2013; Granier et al., 2018; Viana, Pires, Inoue, & Santos, 2018). However, during XCO, the decline in speed was after the start loop (Granier et al., 2018), while in this specific XCC was after the second lap. Despite this finding, new studies must be developed to assess whether this behavior is common in the XCC competition, since faster cyclists have not adopted a positive pacing profile.

It is interesting to note that the cyclists achieving different race time display different pacing profile. Despite majority of cyclists adopted a positive pacing profile during XCC, when pacing was assessed among race time groups, we observed that top cyclists adopted a "W-shaped" pacing, while middle placed finishers performed a positive pacing and bottom performers a parabolic-shaped pacing profile (Abbiss & Laursen, 2008). Although previous research provided support that an even pacing profile is adopted by faster athletes in MTB events (Abbiss et al., 2013; Martin et al., 2012), the results of the current study show that top cyclists adopted a "W-shaped" pacing in an XCC event. This observation suggest that top cyclists adopted a specific distribution of intensity, which was more efficient. During race, cyclists are confronted with a wide range of information involving internal (e.g. physiological response) and external (e.g. action of the opponent) factors, which should be identified and interpreted by the brain. After this, the brain triggers an efferent neural command to select the more appropriate speed (or power output) in order to maximize exercise performance (Renfree, Martin, Micklewright, & St Clair Gibson, 2014; St Clair Gibson et al., 2006). Based on this, we believe that better performance of the top cyclists was due to higher efficiency in processing information and speed adjustments over the XCC, considering the environment situation and state of cyclist in that moment, and not due to the choice of a pacing profile per se. That is, it is probably that faster cyclists had higher accuracy to assess the information and consequently selected the more appropriate speed over the race, which resulted in a W-shaped pacing and superior performance. The parabolic-shaped pacing profile performed by the bottom cyclists consists of a relative fast start, declining middle period followed by an increase in speed during the latter period of the race. This pacing profile has been reported as close to optimal for well-trained cyclists in a simulated 20 km time trial in a cycle ergometer (Thomas, Stone, St Clair Gibson, Thompson, & Ansley, 2013). However, during head-to-head competition, such as in the XCC race, the effects of external factors are more predominant (e.g. behavior of opponent), influencing the pacing decision (Konings & Hettinga, 2018). Therefore, we would like to highlight the relevance of development training methods to improve information processing and decision making of the cyclists during the race. For example, adding one specific cognitive task during cycling exercise, such as adding one or more virtual opponents who adopt a different pacing profile or opponents who only evoke different actions (e.g. accelerate, decelerate) during a racing simulation via computer.

As observed in figure 3, the three groups started the XCC race above of the average speed. This large acceleration at the beginning of the race can lead to excessive fatigue, impairing muscle capacity in sustaining a high exercise intensity (Blain & Hureau, 2017), and causing a reducing in speed over the race, which was observed in the three race time groups. However, as discussed above, the XCC is a mass-start event and its course had a short single track section. Thus, athletes tend to adopt an aggressive start pacing to maintain or gain positions, benefit the riding solo and avoid congestion and crashes in that section, which could influence their overall performance in the race (Arriel, Souza, Sasaki, & Marocolo, 2022). Therefore, we can assume that this fastest start of the three race time groups was a specific strategy for that moment.

Of the five sections of the XCC course, top cyclists were faster than middle and bottom cyclists on sustained non-technical uphill section of the circuit. Although the cyclists of all race time groups were able to maintain a more stable speed (CV across laps) on non-technical uphill section (Table 2), top cyclists were able to maintain higher speed across the laps. Such result was also reported by previous research in XCO format (Abbiss et al., 2013) but on a sustained technical uphill. Perhaps the differences in the characteristics of each circuit, such as race total time, elevation gain, degree of difficulty and number of technical section (Arriel, Souza, Sasaki, & Marocolo, 2022), could explain such difference. However, in this study was not possible to analyze the technical uphill in isolation, which could change the results. During uphill sections, cyclists tend to produce more power output, when compared with a flat section, and significant performance improvements can be obtained from specific uphill training (Alfred Nimmerichter, Eston, Bachl, & Williams, 2012). Moreover, cyclists with more training experience in uphill terrain report lower perceived exertion and blood lactate concentration to a similar relative intensity during an uphill trial (Gandia Soriano, Carpes, Rodríguez Fernández, & Priego-Quesada, 2021). Therefore, it is probable that the non-technical uphill ability of the slower cyclists may be improved through of specific training conditions, consequently improving overall performance in this specific XCC competition.

In addition to non-technical uphill section, top cyclists were also faster than bottom finisher on technical uphill/downhill and non-technical downhill sections. Such result was also reported in a XCM format (Moss et al., 2019). The authors showed that, in addition to adopting a more even speed, better cross-county cyclists were faster on the section composed by short climbs and descents when compared with the less successful performers. It is interesting to note that the faster cyclists of the present study were significantly faster than all other groups on non-technical uphill and it was only faster than bottom cyclists on technical uphill/downhill section. Moreover, the percentage change of speed between the faster and slower riders was higher on non-technical uphill (top vs bottom = 18.8% faster) when compared to other sections (Table 2). Although both non-technical and technical ability could be improved in order to reach success in MTB events (Abbiss et al., 2013; Moss et al., 2019), XCC track course is comprised of less technical sessions, and these have a low degree of difficulty (UCI regulations, Part 4 mountain bike, version from 05 may 2023). Thus, our findings show that the ability to perform a sustained non-technical uphill may be more meaningful than technical uphill/downhill ability to success in the XCC competition, indicating that such fact may be an XCC race characteristic. However, due to observational characteristic of this study, it is unclear whether such advantage can be achieved through of a meaningful improvement in MTB technique (as pedaling technique, stabilize the bike, pedaling seated or standing and technical ability to maneuver), physical ability (as aerobic and anaerobic power) or both.

Average and CV of speed in non-technical flat across laps did not differ among race time groups. Although performance in non-technical flat section can be important to cycling performance (A. Nimmerichter, Williams, Bachl, & Eston, 2010), in the present study, cyclists used this section to hydrate and/or to energy replacement. This indicates that cyclists did not use this section to gain advantage on their opponent. Therefore, it is unclear whether riding faster on flat could be an important determinant to performance in this XCC course. Moreover, CV of speed across laps and average speed in technical downhill was also not different among race time groups. Again, although MTB events require that cyclists have high degree of technical ability in order to gain advantage on their less technical opponent and/or decrease time lost in other sections of the course, in the XCC track profile these technical sections have a relatively low degree of difficulty, which could benefit the less technical cyclists. Therefore, it appears that having a greater technical downhill ability does not seem to be a determining factor in the XCC competition performance.

To data from the current study, we can suggest that athletes incorporate in their training routine methods to enhance their ability of information processing over the race in order to select the more appropriate speed. Moreover, they must include specific training for improve performance in sustained non-technical uphill section in order to achieve superior performance in the XCC. However, we would like to highlight some limitations of this study. As the analyses of the present study were conducted only on a single XCC course, such response in pacing profile could be influenced by topographic profile, track settings (as difficult technical) and race dynamics of other events. Moreover, it was not possible to analyze the technical climb in isolation. Therefore, it is not appropriate to extrapolate the results to all XCC competitions. In this regard, future research should assess a larger number of XCC races within the same analysis. Lastly, due to the observational characteristic of this study, we did not carry out performance test to define and classify the training status of the cyclists.

5. Practical Applications.

To data from the current study, we can suggest that athletes incorporate in their training routine methods to enhance their ability of information processing in order to select the more appropriate speed over entire race. Moreover, they must include specific training for improve performance on sustained non-technical uphill section in order to achieve superior performance in this specific XCC circuit.

6. Conclusions

Although the majority of the MTB cyclists adopt a positive pacing profile during XCC, faster cyclists tend to adopt a "W-shaped" pacing profile and were found to be faster on sustained non-technical uphill section, technical section composed by shorter uphill/downhill and non-technical downhill. However, this advantage was greater on non-technical uphill section. Therefore, our finding show that better performance in this specific XCC circuit was associated with the higher ability to adjustment in speed across the laps and higher speed mainly on sustained non-technical uphill cycling.

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Conflicts of Interest: The authors declare no conflict of interest.

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