

Pacing strategy during cross-country short track mountain bike event

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Abstract

Although in recent years, cross-country short track (XCC) mountain biking became more popular among athletes and coaches, no study has analyzed the main determinants of performance in this modality. Thus, this study investigates performance and pacing profile of professional cross-country cyclists on different technical sections during a XCC competition. Twenty male professional cross-country cyclists (25.9 ± 5.4 years; eight under 23 and twelve elite), performed 6 laps of a XCC 2020 UCI International Mountain Bike Cup. Average speed (lap by lap and in five different technical sections of the track) were analyzed according to athletes, categories and race performance group. For race performance analyses, cyclists were divided into 4 groups (1-4; $n=5$ each), according to total race time, presenting group 1 the better performance. In general, XCC athletes adopted a positive pacing profile during competition but no differences in speed over the race or in each circuit section were found between categories ($p > 0.05$). Race performance groups adopted different pacing profiles: group 1 maintained a more even pacing profile, groups 2 and 3 adopted a positive pacing profile and group 4 adopted a reverse J-shaped pacing profile. No difference in speed was found between categories across track sections. Group 1 was 17.9% and 8.3% faster than the group 4 ($p < 0.05$) on the non-technical uphill section and more technical uphill/downhill section, respectively. A general positive pacing profile during XCC is adopted by the mainly of athletes and this choice of pacing profile is influenced by race performance, regardless of cyclist category. Furthermore, physical fitness is more relevant than technical ability in this competition.

Introduction

Cross-country short track (XCC) is mountain biking (MTB) event that involves all riders aged 17 or over. This competition is performed on a closed circuit of approximately 2.0 km lasting 20 to 60 minutes over diverse types of terrain such as forest tracks, earth or gravel paths with repeated uphill and downhill sections (Union Cycliste Internationale Cycling regulations, version on 11.02.2020). Despite Cross-Country Olympic (XCO) being the most popular event in MTB, in recent years, XCC is drawing the attention of athletes and coaches because, in addition to defines the starting grid of the XCO, this competition adds points to the Union Cycliste Internationale (UCI) world ranking and, in the year 2021, a world XCC championship will be developed. However, the main determinants that lead athletes to successful XCC performance are currently lacking.

Among these determinants of performance, pacing strategy is recognized as an important parameter for a better understanding about how the athletes regulate their velocity (or effort/energy expenditure) during competitions in order to optimize performance (ABBISS; LAURSEN, 2008). On the different tasks and exercise conditions, pacing strategy presents different profiles, such as positive (i.e. when speed gradually declines throughout the event), negative (i.e. when speed increases over the event), even (when speed deviates little the mean race speed), parabolic-shaped (i.e. when speed declines over the race but tend to increase during the latter section of the event), all-out and variable (ABBISS;

LAURSEN, 2008). For short time exercises (< 30 seconds), all-out pacing profile seems to be beneficial, while in more prolonged (> 2 min) and ultra-endurance exercise (> 4 hours), as in mountain biking events, the athletes tend to adopt a more even or variable pacing and positive pacing profile, respectively (ABBISS; LAURSEN, 2008). However, authors have shown that, within the same competition format, the choice of the pacing profile can be influenced by age, performance level (ABBISS et al., 2013; LIMA-SILVA et al., 2010), and influenced by external factors, including importance of the race and behavior of the opponent (KONINGS; HETTINGA, 2018).

In MTB format, pacing profile differs according to category, performance level (ABBISS et al., 2013) and type of event, which is due to race duration, accumulated altimetry and distance of circuit (GRANIER et al., 2018; MOSS et al., 2019). For example, in XCO competition, the cyclists adopted a positive pacing (GRANIER et al., 2018), while in the cross-country marathon (XCM), a more prolonged event, they adopted a variable pacing profile (MOSS et al., 2019). Moreover, during XCO competition, elite top finisher adopted a more even pacing while elite bottom finishers adopted positive pacing profile (ABBISS et al., 2013). Considering that XCC presents modified track course profile, shorter race time and circuit distance than XCO and XCM (Union Cycliste Internationale Cycling regulations, version on 11.02.2020), it is probable that cyclists of different age and performance level could adopt different pacing profile during this competition in order to optimize their performance. However, no study has yet investigated the pacing profile adopted by cyclists in XCC. Finding an optimal pacing profile for XCC could help to develop a more effective training routine to ensure the success in this competition.

Furthermore, other important requirement for success in MTB is technical ability (IMPELLIZZERI; MARCORA, 2007). The variety of terrains with repeated uphill and downhill on technical sections found during MTB, in fact, requires a high degree of technical ability over the competition (IMPELLIZZERI; MARCORA, 2007). Previous research has demonstrated that, during a XCO competition, elite bottom finishers spend more time in technical uphill sections, compared with top finishers athletes, which could explain, at least in part, the overall performance different between them (ABBISS et al., 2013). Despite this, it is known that the XCC track course is comprised of few technical sections, and these have a low degree of difficulty (Union Cycliste Internationale Cycling regulations, version on 11.02.2020). In this context, the ability to tolerate fatigue during XCC could be more relevant to success in this competition than technical ability. Thus, the aims of this study were to investigate pace strategy adopted by professional cross-country cyclists and assess their performance on technical and non-technical uphill and downhill sections during a XCC competition, examining if there is influence of category and performance level on these parameters.

Methods

Participants

Twenty male professional cross-country cyclists (25.9 ± 5.4 yrs; range: 19 – 39 yrs; categories: eight under 23 and twelve elite) participated in this study. In addition to categories, they were divided into

four groups according to total race time, using interquartile ranges (MOSS et al., 2019). Therefore, cyclists who completed the race in less time was considered the quicker and so sequentially the groups were formed. The 4 groups were defined as first fastest cyclists (group 1) [n = 5; 24.6 ± 4.3 yrs; range: 19 - 30 yrs], second fastest cyclists (group 2) [n = 5; 26.2 ± 5.1 yrs; range: 20 - 32 yrs], third fastest cyclists (group 3) [n = 5; 27.0 ± 7.8 yrs; range: 21 - 39 yrs], and fourth fastest cyclists (group 4) [n = 5; 25.8 ± 5.2 yrs; range: 20 - 32 yrs]. All cyclists were registered by the local cycling confederation and they had experience in XCC racing settings. This study was performed in accordance with the Declaration of Helsinki, and approved by the local ethical committee (number 2.250.458) for human experiments.

XCC competition and track course profile

XCC competition was performed during 2020 UCI International Mountain Bike Cup, which involved six laps on a circuit of approximately 2 km. All cyclists of both under 23 and elite categories performed XCC race at the same time, circuit profile and number of laps. Total distance cycled (13.8 km), total elevation gain (280 m), altitude (998 m), temperature (24.8 ± 1.4 °C) and average speed of winner of the race (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 few single tracks, obstacles (rock gardens, tree roots and mud), narrow turns and technical sections when compared with others mountain biking competitions (ABBISS et al., 2013; MOSS et al., 2019). To assess ability to tolerate fatigue and technical ability during XCC, we decided to separate the XCC track course into five sections according to topography (uphill, downhill and flat), technical and non-technical sections. Section one was composed of a flat course (grade of 1.2%) without narrow paths and technical stretches. Of the 280 m cycled, approximately 190 m were completed on tarmac and the other 90 m on dirt track roads. Section two had 550 m sustained climbing on cobblestones (~450 m) and dirt track roads (~100 m) without technical stretches. Cyclists climbed from an elevation of ~964 m to 997 m with an average of 4.8% and a maximum grade of 12.4%. Section three was the first technical section of a ~250 m sustained descents (average of 8.5% and maximum of 23.9% grade) with turns in tight areas and short single track on dirt track roads trails. Section four, cyclists completed ~560 m composed for a short climb (~190 m and average of 10.9% grade) and descents (~200 m and average of 9.1% grade) followed by another short climb (~170 m and average of 8.3% grade). This section involved technical (jump sections, and a short rock garden) and non-technical piloting on dirt track roads and a short single track with very tight curve. Section five involved approximately 670 m of a sustained downhill (from an elevation of ~982 m to ~962 m) and short flat stretches on dirt track roads. Final course of this section was performed on tarmac and involved a tight curve before finish line. These technical portions were assessed by the researcher involved in this study. Figure 1 shows the XCC course profile.

Data collection

Total time, distance and speed over entire race were recorded through of individual devices (Garmin® Edge, Kansas City, United States; and Polar®, Finland), which posteriorly were downloaded directly in the Strava® program. All the data were analyzed via Excel software by two independent reviewers. We correlated total race time recorded by individual devices with the time recorded by the official system of the International Mountain Bike Cup (ABBISS et al., 2013), 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 percentage speed coefficient of variation (%CV) across laps and of each section across laps was determined using average speed (AS) divided by standard deviation (SD) multiplied by 100 [i.e. $\%CV = (AS/SD)*100$].

Statistical analysis

IBM SPSS (Version 23) and GraphPad (PRISM®, 6.0, San Diego, USA) statistical program were used for performed the data analyses. Shapiro-Wilk test was used for checked the normality of the data, however, for the categorical variables a non-parametric statistic was adopted. To compare total race time, average race speed and %CV of speed between under 23 and elite athletes, and among race performance 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 analyze average speed across the laps (Figure 2), and average speed and %CV of speed among distinct sections (Table 2). In addition, the same test was used to compare the average speed of the section in each lap (Figure 3). Separate two-way ANOVA mixed model was conducted for each independent variable (categories and race performance) to analyze, within and among groups, the average speed across laps, and average speed and %CV of speed among distinct sections. When necessary, a Bonferroni's post-hoc test was employed. For measurement of the correlations between total race time and %CV of speed, and average race speed and %CV of speed of overall cyclists, Pearson's bivariate correlations test was performed, using a scale to analyze the correlation coefficient (proposed by Hopkins - www.sportsci.org), where: < 0.1 , trivial relationship; $0.1 - 0.3$, low; $0.3-0.5$ moderate; $0.5-0.7$, strong; $0.7-0.9$, very strong; > 0.9 , nearly perfect. The level significance adopted was $p \leq 0.05$.

Results

All Athletes

All athletes performed XCC race with a total distance of 13.8 km and duration of 38 ± 1 min without injure or faced mechanical problems. Average race speed was of 21.6 ± 0.7 km/h with %CV of speed across laps of $2.8 \pm 1.1\%$ (Table 1). During competition, average speed was similar between Lap 1 and Lap 2 ($p = 1.00$), decreased from the Lap 2 for Lap 3 ($p < 0.01$), and it was similar from the lap 3 until Lap 6 ($p > 0.05$) (Figure 2).

Cyclists were significantly quicker in the section 1 ($p < 0.05$) and slowest in the section 4 ($P < 0.05$), but %CV of speed across each section was significantly higher in the section 1 ($p < 0.05$) and lower in the section 5 ($p < 0.05$) (Table 2). In section 1, speed decreased over the laps ($p < 0.05$). In section 2, after lap 1 and lap 2 ($p = 1.00$), speed significantly decreased from the Lap 2 for Lap 3 ($p = 0.01$), and was maintained from the Lap 3 until Lap 6 ($p > 0.05$). In section 3, speed increased from lap 1 for lap 2 ($p < 0.01$), which was maintained until lap 6 ($p > 0.05$). In section 4, no speed change was found ($p > 0.05$). In section 5, speed was maintained from lap 1 until lap 3, significantly decreased in lap 4 and lap 5 compared with lap 1 ($p < 0.01$), and it increased from the Lap 5 for lap 6 ($p < 0.05$) (Figure 3).

No significant correlation was found between cyclists *racetime* and %CV of speed across laps ($r = 0.230, p > 0.05$), and *betweencyclists* average speed and %CV of speed across laps ($r = -0.251, p > 0.05$).

Under 23 and elite

Total race time, average race speed and %CV of speed across laps were similar between under 23 and elite categories ($p > 0.05$) (Table 1). Pacing profile adopted during the XCC competition by both categories was similar ($p > 0.05$). They maintained a similar speed in Lap 1 and Lap 2 ($p > 0.05$), but decreased in Lap 3 (under 23, $p < 0.01$; elite, $p < 0.01$). After this reduction, cyclists of both categories were able to maintain a similar speed until Lap 6 ($p > 0.05$). This information is displayed in figure 4.

Both under 23 and elite were significantly quicker in the section 1 ($p < 0.05$) and slowest in the section 4 ($p < 0.05$), and they presented a higher %CV of speed in the section 1 and a lower in the section 5. No significant difference was found for speed and %CV of speed in each circuit section between groups ($p > 0.05$) (Table 2).

Race performance

Total race time and average race speed were significantly different among race performance groups. Average race speed was significantly higher in group 1 ($p < 0.05$), and sequentially decreased for each slower group ($p < 0.05$). Total race time was lower in group 1 ($p < 0.05$), and sequentially increased for each slower group ($p < 0.05$). No significant change in %CV of speed across laps was found among groups ($p > 0.05$) (Table 1). However, group 1 maintained a significantly more even pacing over the race, while groups 2 and 3 adopted a positive pacing and group 4 a parabolic-shaped pacing profile (Figure 5).

In Lap 1 and Lap 2, group 1 was significantly faster than group 4 ($p < 0.05$), but similar when compared with the other groups ($p > 0.05$). In lap 3, lap 5 and lap 6, both groups 1 and 2 were

significantly faster than groups 3 and 4 ($p < 0.05$). However, in lap 4, group 1 was significantly faster than all other groups ($p < 0.05$, Figure 5).

During race, all race performance groups were significantly quicker in the section 1 ($p < 0.05$) and slowest in the section 4, and they presented a higher %CV of speed in the section 1 and a lower in the section 5 of the XCC track course. Group 1 was significantly faster groups 2, 3 and 4 in the section 2 (groups: 1 vs 2 = 7.4% faster; 1 vs 3 = 12.1% faster; 1 vs 4 = 17.9% faster), and was faster than group 4 in the section 4 (1 vs 4 = 8.3% faster) ($p < 0.05$). Furthermore, group 2 was significantly faster ($p < 0.05$) than group 4 in the section 2 (11.4% faster) (Table 2).

Discussion

The purposes of this study were to investigate pacing profile adopted by professional cross-country cyclists and assess their performance on technical and non-technical uphill and downhill sections during a XCC competition, examining if there is influence of the categories and performance level on these parameters. Our main findings were that, after faster first and second lap, cyclists significantly reduced speed followed by an even pacing until the end of the race, which was enough to be considered as a positive pacing profile. The pacing profile did not differ between under 23 and elite categories, but pacing profile was influenced by race performance during XCC competition, with the 1st group (i.e., quicker cyclists) performing competition in a more even pacing profile. In addition, both categories performed all track sections on the similar speed. However, 1st group was faster than 2nd, 3rd and 4th groups during a sustained non-technical climbing section (section 2) and was faster than 4th group during a section that involved technical uphill/downhill (Section 4).

This is the first study to analyze the pacing profile during XCC competition. Following the actual UCI recommendations (4.2.008), XCC race duration must be of 20 to 60 minutes, which is in line with our value (38 ± 2 min). Average race speed was of 21.6 ± 0.7 km/h with %CV of speed across laps of $2.8 \pm 1.1\%$. In circuit MTB events, these results indicate that the XCC competition has a high average speed and lowest %CV of speed across laps (GRANIER et al., 2018). During XCC competition, cyclists in general adopted a positive pacing profile. After first and second lap, speed significantly declined in lap 3, followed by a similar speed until last lap (Figure 2). This pacing profile may be explained on the two hands. On the one hand, as the reduction in speed happened from lap 2 to lap 3, the excessive peripheral fatigue developed during lap 1 and lap 2 may have increased the activity of the metabosensitive group III-IV muscle afferents that are responsible for restrain muscle activation, impairing, therefore, the muscle capacity in sustaining a high exercise intensity (BLAIN; HUREAU, 2017). After this decline, the excessive peripheral fatigue was blunted, and the cyclists were able to maintain similar speed until the end of the race. On the other hand, the positive pacing profile can be due to XCC track profile and competition regulations. In mass-start event, as in the XCC competition, athletes tend to adopt an aggressive race start in order to avoid congestion and crashes in sections composed of single track and turns in tight

areas, which could impair their overall performance. Indeed, across laps we can observe that athletes were faster in the section 1 and slower in section 3 (section composed of a single track) on the first lap, showing that cyclists really adopted an aggressive race start and probably experienced a congestion and/or crashes after this. After second lap, cyclists placed themselves in better positions, allowing them to reduce speed. Previous MTB studies support this hypothesis (GRANIER et al., 2018; IMPELLIZZERI; MARCORA, 2007; VIANA et al., 2018), mainly in the XCO competition (GRANIER et al., 2018; VIANA et al., 2018). However, during XCO, decline in speed was after first lap, while in XCC was after second lap. It is possible that such differences appear because of the shortest lap time in the XCC (~6 min) compared with XCO (~13 min) (GRANIER et al., 2018), showing that cyclists needed of more one lap to achieve a best position. Therefore, we can infer that the positive pacing profile adopted by cyclists during XCC was due to the specific starting procedures and/or inability to maintain intensity due to excess fatigue after the second lap.

During XCC competition, both elite and under 23 athletes adopted a positive pacing profile, showing that the category does not influence pacing profile. In addition, average speed across laps and speed on technical and non-technical uphill/downhill sections were significantly similar between them. Considering that the pacing profile can be influenced by the position of cyclists on the starting grid (VIANA; INOUE; SANTOS, 2013) and by performance level (ABBISS et al., 2013), we can infer that, in the present study, cyclists of both categories were placed on the similar starting grid and were at the same performance level. Although a decrease in endurance performance is correlated with a decline in physiological functions with advancing age (TANAKA; SEALS, 2003), previous investigation demonstrated that this performance loss in mountain bikers can occur after 40 years old in endurance event (HAUPT et al., 2013). In our study, the oldest cyclist in the elite category was 39 years old. Therefore, endurance performance of cyclists in this category was preserved.

Among race performance groups, we observed that the 1st group adopted a more even pacing profile (i.e. more consistent average speed over the entire race), while the 2nd and 3rd groups performed in a positive pacing and 4th group a reverse J-shaped pacing profile (ABBISS; LAURSEN, 2008). Although the utility of an even pacing profile has been questioned (THOMAS et al., 2013), the results of the current study and previous research (ABBISS; LAURSEN, 2008), including MTB events (ABBISS et al., 2013), provided support for adopting an even pacing profile for optimize performance in more prolonged events. Therefore, despite cyclists in general have adopted a positive pacing, adopt a more even pacing profile appear to be more beneficial to achieve successful in XCC competition. However, it is important to highlight that the choice of the pacing profile by the groups could be due to start position of the cyclist (VIANA; INOUE; SANTOS, 2013). Again, it is not surprising that athletes adopt an aggressive start race to place themselves in the front positions to benefit from riding solo, avoiding crashes and congestions on the technical sections such as on the single track. However, bad placed cyclists on the starting grid tend to increase their relative speed more than better placed cyclists. This larger acceleration in an initial period can lead to an additional energy cost (SANDALS et al., 2006) and excessive peripheral fatigue (THOMPSON et al., 2003), leading the cyclists to reduce speed after fast start. Therefore, the 2nd and 3rd group cyclists may have adopted a positive pacing profile likely influenced by these specific starting

procedures. On the other hand, 4th group adopted a pacing profile consisting of a relative fast start, declining middle period followed by an increase in speed during the latter period of the race. This parabolic pacing profile has been reported as close to optimal for well-trained cyclists in a simulated 20 km time trial (THOMAS et al., 2013). However, during head-to-head competition, such as in XCC race, the effects of external factors are much more predominant (e.g. behavior of opponent), which can determine pacing regulation (KONINGS; HETTINGA, 2018). In this way, we can then speculate that adopting a parabolic pacing profile does not appear to be beneficial in XCC competition.

Furthermore, 1st group was faster than 4th group over entire the race, including section 2 of the circuit composed of sustained non-technical uphill and the section 4 composed for short technical uphill and downhill. Such results were also reported in a XCO world championship format. Abbiss et al. (2013) showed that quicker mountain cyclists adopted a more even pacing and were faster on the technical sections when compared with the slower cyclists group. However, during non-technical uphill section, speed was similar between the cyclists, which is in contrast with our result. In this way, we can suggest that quicker cyclists of the present study had, in addition to superior technical ability, a greater physical fitness compared with the slower cyclists to support the demands imposed by the XCC course (IMPELLIZZERI; MARCORA, 2007). Therefore, both physical and technical ability should be improved in order to reach success in this competition. However, for the cyclists of the 4th group, a greater attention should be provide in physical fitness, since percentage change of speed compared with the 1st group on the non-technical uphill section (section 2) (1st vs 4th = 17.9% faster) was higher than technical uphill/downhill section (section 4) (1st vs 4th = 8.3% faster). Thus, it is clear that the ability to tolerate fatigue seems to be more relevant than technical ability to success in XCC competition.

Lastly, we would like to highlight some limitations. As the analyses of the present study were conducted only on a single XCC course, such response in pacing strategy could be influenced by topographic profile, track settings (as difficult technical) and race dynamics of other events. Thus, future research should consider and assessed a higher number of XCC events within the same analysis. Moreover, due to observational characteristic of this study, we did not carry out performance test to define and classify training status of the cyclists.

Conclusion

Cyclists in general adopt a positive pacing profile during XCC likely influenced by specific starting procedures. In this competition, pacing profile strategy is seen to be influenced according to race performance, but not to category. Furthermore, the first fastest cyclists were found to be faster than fourth fastest cyclists on a non-technical uphill section and a technical uphill/downhill section. This advantage was greater in the non-technical uphill section, showing that for XCC performance, physical fitness is more relevant than technical ability. Therefore, it is probable that adopting a more even pacing profile and enhancing physical fitness, the XCC performance can be improved.

Declarations

Competing interests:

The authors declare no competing interests.

References

- ABBISS, C. R. et al. The distribution of pace adopted by cyclists during a cross-country mountain bike World Championships. **Journal of Sports Sciences**, v. 31, n. 7, p. 787–794, 2013.
- ABBISS, C. R.; LAURSEN, P. B. Describing and understanding pacing strategies during athletic competition. **Sports Medicine (Auckland, N.Z.)**, v. 38, n. 3, p. 239–252, 2008.
- BLAIN, G. M.; HUREAU, T. J. Limitation of fatigue and performance during exercise: the brain-muscle interaction. **Experimental Physiology**, v. 102, n. 1, p. 3–4, 1 jan. 2017.
- GRANIER, C. et al. Power Output and Pacing During International Cross-Country Mountain Bike Cycling. **International Journal of Sports Physiology and Performance**, v. 13, n. 9, p. 1243–1249, 1 out. 2018.
- HAUPT, S. et al. The age-related performance decline in ultraendurance mountain biking. **Research in Sports Medicine (Print)**, v. 21, n. 2, p. 146–158, 2013.
- IMPELLIZZERI, F. M.; MARCORA, S. M. The physiology of mountain biking. **Sports Medicine (Auckland, N.Z.)**, v. 37, n. 1, p. 59–71, 2007.
- KONINGS, M. J.; HETTINGA, F. J. Pacing Decision Making in Sport and the Effects of Interpersonal Competition: A Critical Review. **Sports Medicine (Auckland, N.Z.)**, v. 48, n. 8, p. 1829–1843, ago. 2018.
- LIMA-SILVA, A. E. et al. Effect of performance level on pacing strategy during a 10-km running race. **European Journal of Applied Physiology**, v. 108, n. 5, p. 1045–1053, mar. 2010.
- MOSS, S. L. et al. Pacing during a cross-country mountain bike mass-participation event according to race performance, experience, age and sex. **European Journal of Sport Science**, v. 19, n. 6, p. 793–801, jul. 2019.
- MUKAKA, M. A. **Statistics corner: A guide to appropriate use of correlation coefficient in medical research**. Disponível em: <<https://pubmed.ncbi.nlm.nih.gov/23638278/>>. Acesso em: 2 dez. 2020.
- SANDALS, L. E. et al. Influence of pacing strategy on oxygen uptake during treadmill middle-distance running. **International Journal of Sports Medicine**, v. 27, n. 1, p. 37–42, jan. 2006.
- TANAKA, H.; SEALS, D. R. Invited Review: Dynamic exercise performance in Masters athletes: insight into the effects of primary human aging on physiological functional capacity. **Journal of Applied Physiology (Bethesda, Md.: 1985)**, v. 95, n. 5, p. 2152–2162, nov. 2003.

THOMAS, K. et al. The effect of an even-pacing strategy on exercise tolerance in well-trained cyclists. **European Journal of Applied Physiology**, v. 113, n. 12, p. 3001–3010, dez. 2013.

THOMPSON, K. G. et al. The effect of even, positive and negative pacing on metabolic, kinematic and temporal variables during breaststroke swimming. **European Journal of Applied Physiology**, v. 88, n. 4–5, p. 438–443, jan. 2003.

VIANA, B. F. et al. Pacing Strategy During Simulated Mountain Bike Racing. **International Journal of Sports Physiology and Performance**, v. 13, n. 2, p. 208–213, 1 fev. 2018.

VIANA, B. F.; INOUE, A.; SANTOS, T. M. The influence of start position on even-pacing strategy in mountain bike racing. **International Journal of Sports Physiology and Performance**, v. 8, n. 4, p. 351, jul. 2013.

Tables

Table 1: Total time, average speed and %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 (%)
<i>General</i>			
All athletes	38 ± 1.3	21.6 ± 0.7	2.8 ± 1.1
<i>Categories</i>			
Sub-23	39 ± 1.4	21.4 ± 0.8	3.2 ± 1.1
Elite	38 ± 1.2	21.7 ± 0.7	2.5 ± 1.0
<i>Race time</i>			
1st	37 ± 0.1 ^{b,c,d}	22.5 ± 0.1 ^{b,c,d}	2.1 ± 0.6
2nd	38 ± 0.5 ^{a,c,d}	22.0 ± 0.3 ^{a,c,d}	2.8 ± 0.6
3rd	39 ± 0.4 ^{a,b,d}	21.3 ± 0.2 ^{a,b,d}	3.7 ± 0.9
4th	40 ± 0.3 ^{a,b,c}	20.7 ± 0.2 ^{a,b,c}	2.5 ± 1.5

Data are mean ± DP. %CV = coefficient of variation of speed. ^a p < 0.05 compared with group 1; ^b p < 0.05 compared with group 2; ^c p < 0.05 compared with group 3; ^d p < 0.05 compared with group 4.

Table 2: Average speed and %CV of speed across laps of cyclists according to general, categories and race time groups in each track section.

	Section 1		Section 2		Section 3		Section 4		Section 5	
<i>General</i>	Km/h	%CV	Km/h	%CV	Km/h	%CV	Km/h	%CV	Km/h	%CV
All athletes	32.7*	15.5*	23.2	8.7	19.3*	10.1	17.3*	3.8*	23.7	2.6*
<i>Categories</i>										
Under 23	32.4*	15.0	23.0	9.8	19.4*	9.2	17.0*	3.2	23.7	3.0
Elite	32.9*	15.8	23.4	7.9	19.2*	10.7	17.5*	4.1*	23.7	2.3*
<i>Race time (groups)</i>										
1	31.8*	17.1*	25.6 ^{b,c,d}	7.1	19.7	7.5	18.1 ^d	3.1	24.2	2.3
2	34.5*	14.0	23.7 ^d	7.3	18.9	9.0	17.5	4.6	24.2	2.9
3	32.9*	16.0	22.5	10.6	19.0	13.6	17.1*	4.0	23.4	2.9
4	31.5*	14.9	21.0	9.5	19.4	10.3	16.6*	3.4	23.2	2.3

Data are mean. * $p < 0.05$ compared with all other sections of the same group; comparison within the same section: ^a $p < 0.05$ compared with group 1; ^b $p < 0.05$ compared with group 2; ^c $p < 0.05$ compared with group 3; ^d $p < 0.05$ compared with group 4.

Figures

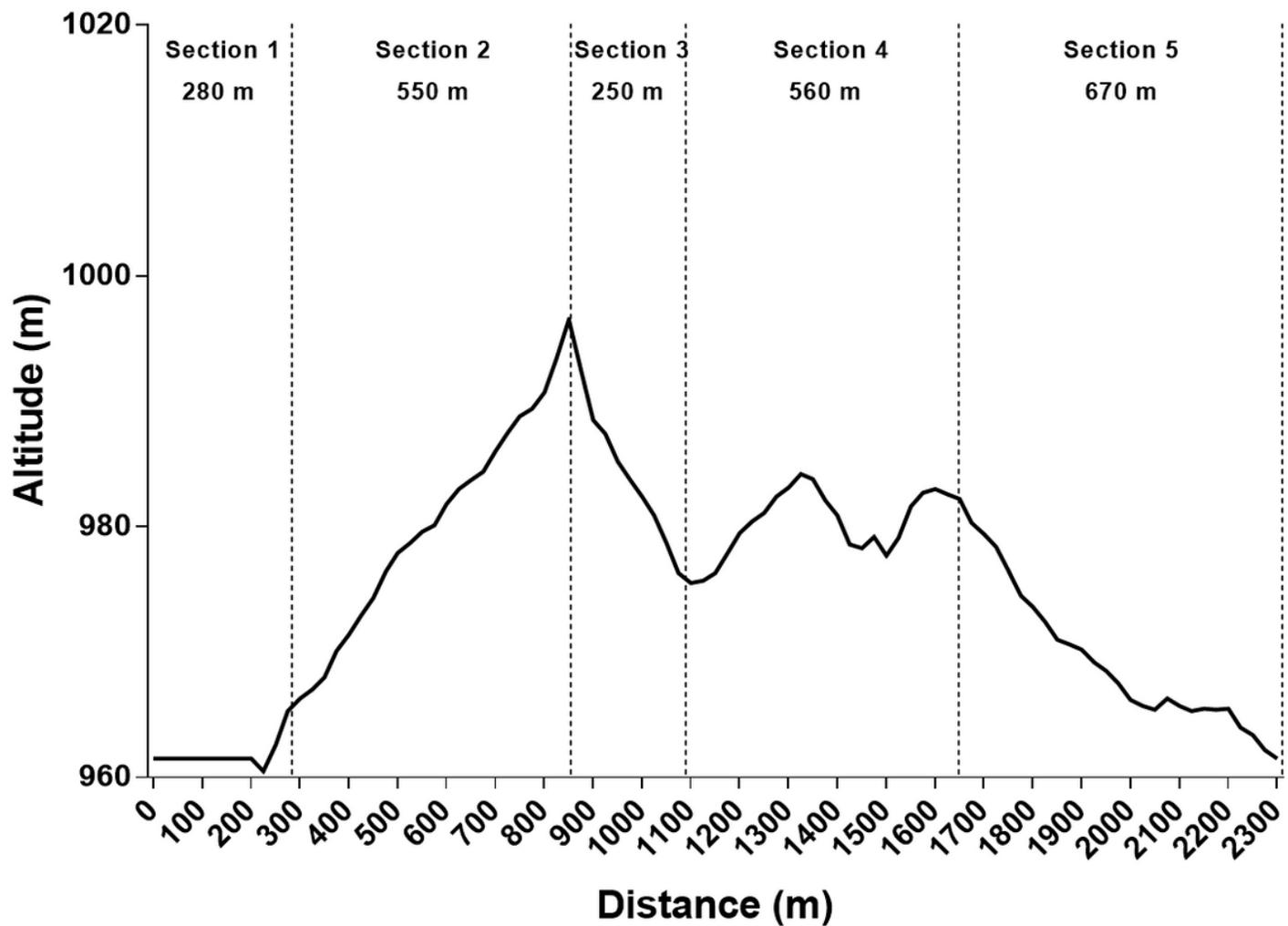


Figure 1

Cross-country short track (XCC) course profile and location of sections for an individual lap.

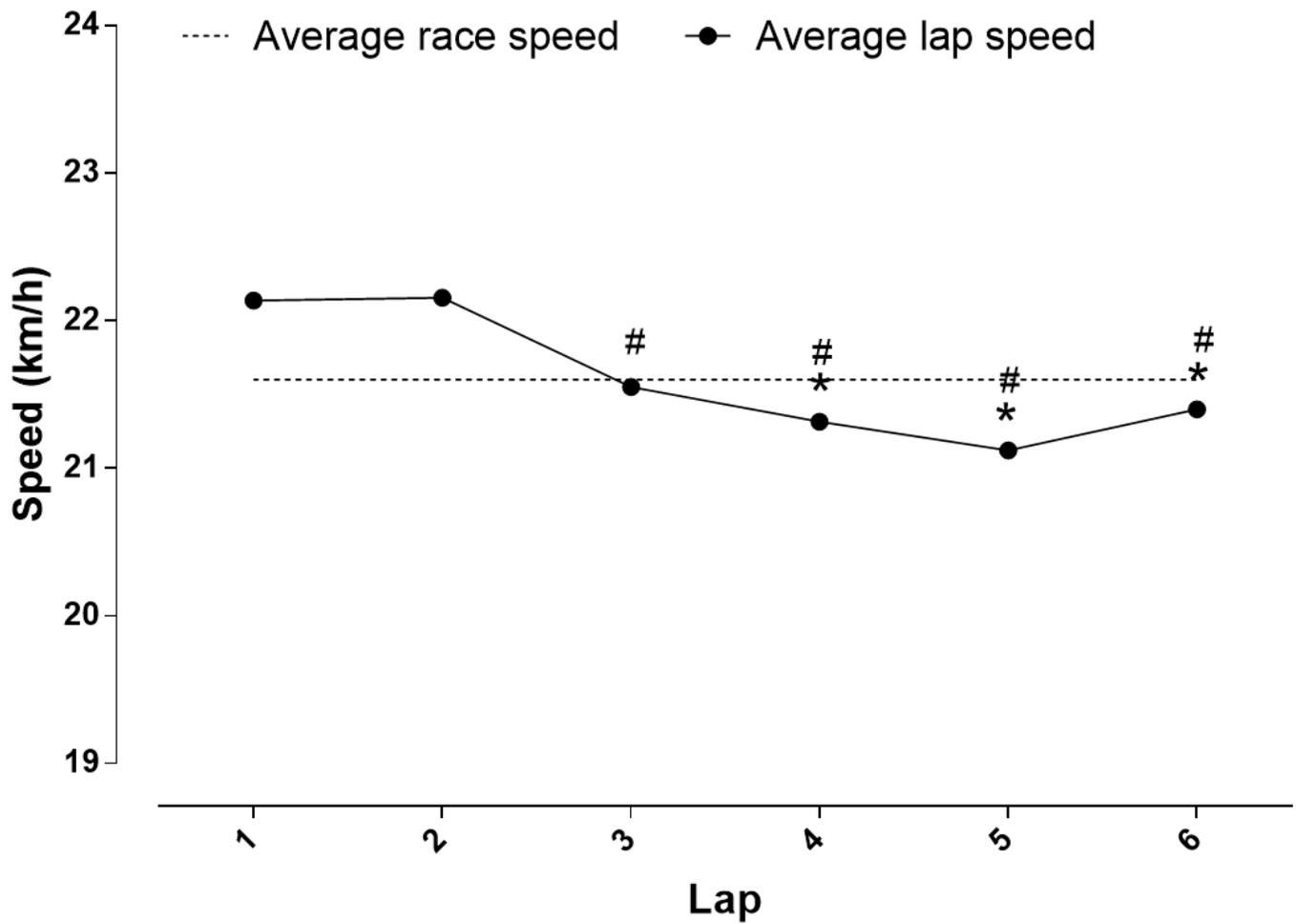


Figure 2

Pace strategy according to all cyclists over the entire XCC competition. * $p < 0.05$ compared with Lap 1; # $p < 0.05$ compared with lap 2. Data are expressed as mean \pm SD

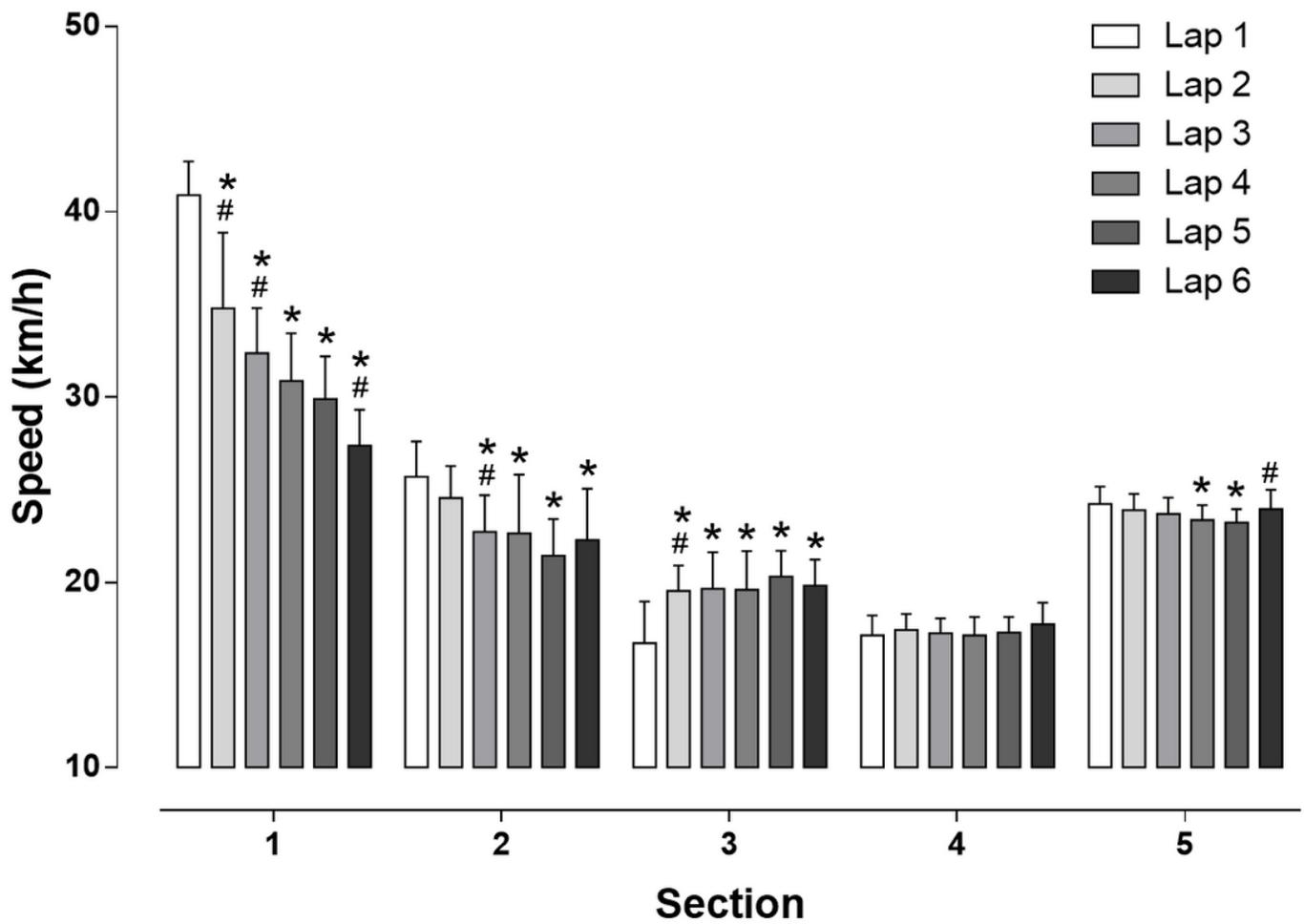


Figure 3

Average speed of each section in each lap to all cyclists. * p < 0.05 compared with Lap 1; # p < 0.05 compared with previous lap.

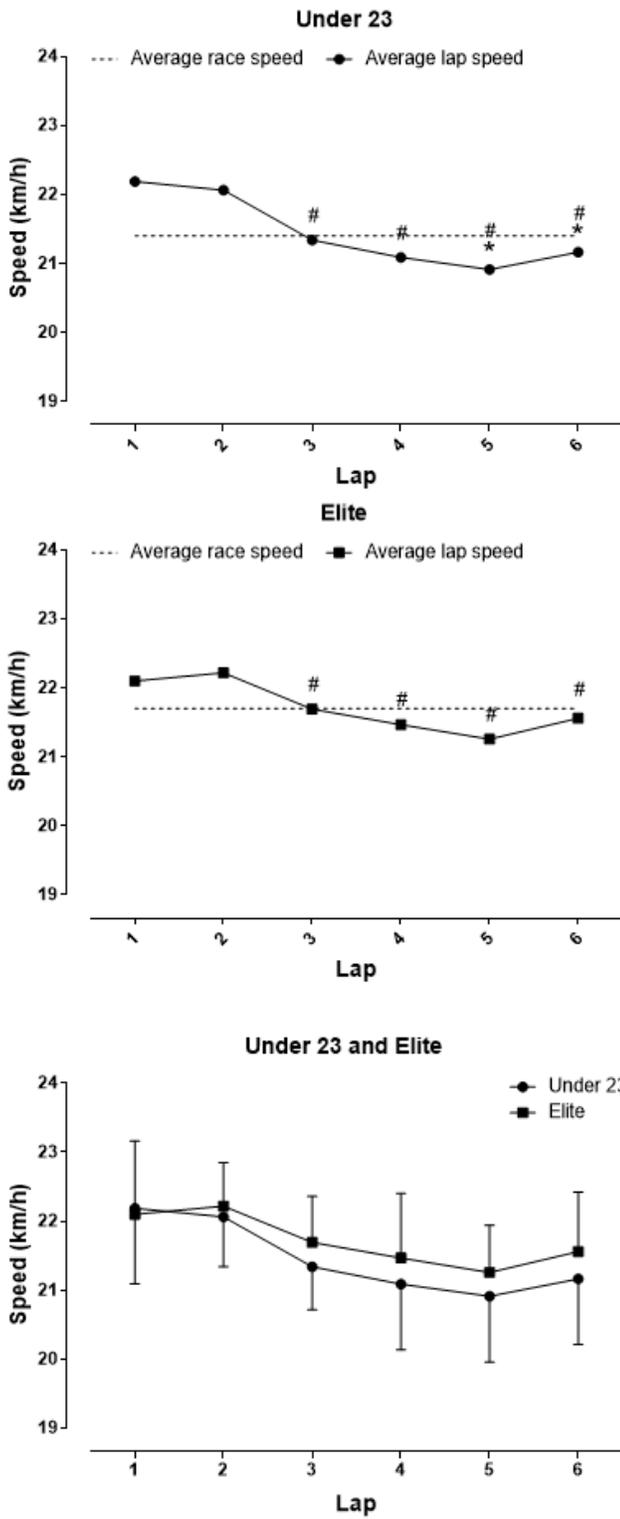


Figure 4

Pace strategy according to under 23 and elite categories over the entire XCC competition. * $p < 0.05$ compared with Lap 1; # $p < 0.05$ compared with lap 2.

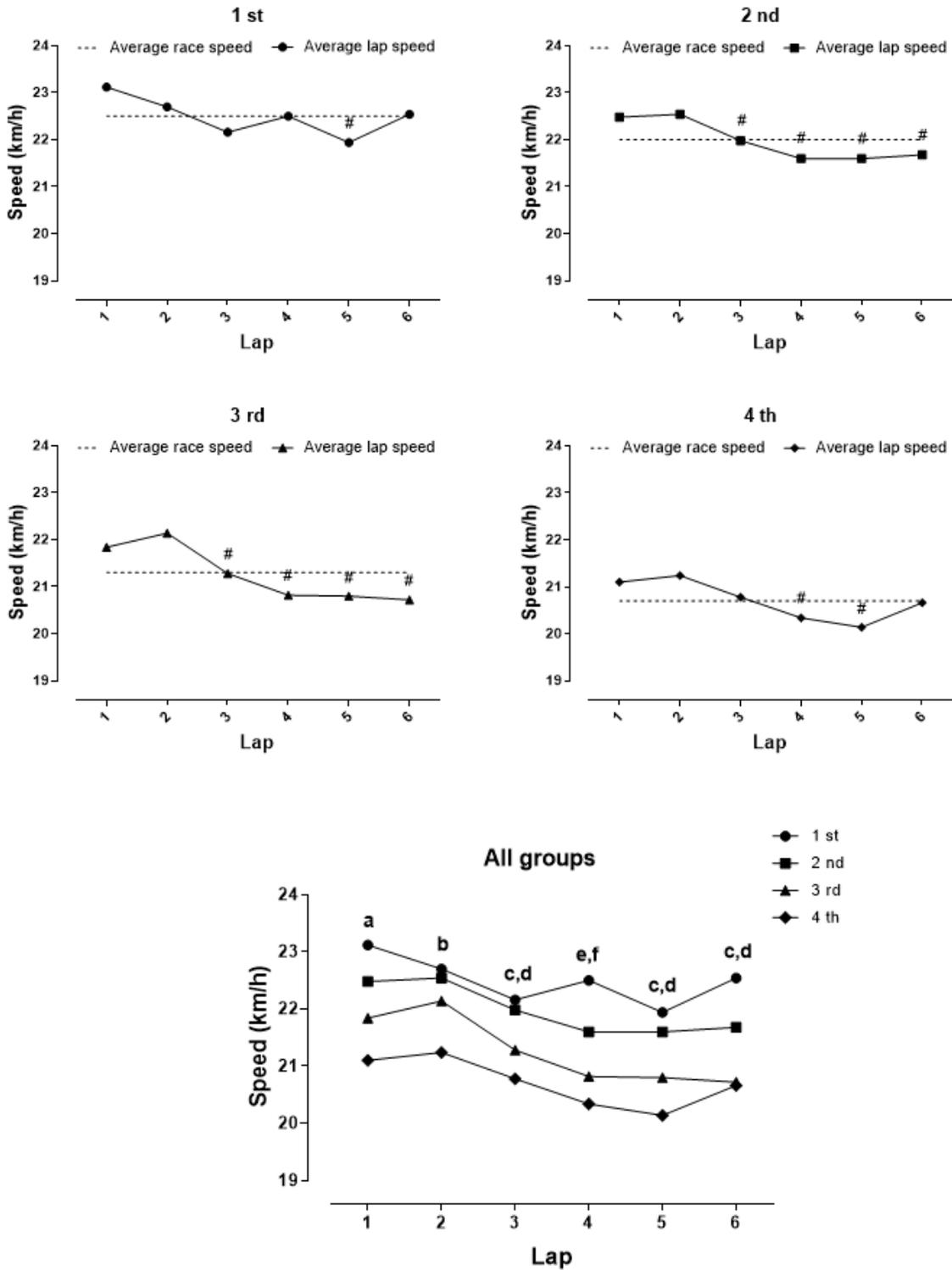


Figure 5

Pace strategy according to race time group over the entire XCC competition. * $p < 0.05$ compared with Lap 1; # $p < 0.05$ compared with Lap 2; a $p < 0.05$ = group 1 compared with 4; b $p < 0.05$ = group 4 compared with 1, 2 and 3; c $p < 0.05$ = group 1 compared with 3 and 4; d $p < 0.05$ = group 2 compared with 3 and 4; e $p < 0.05$ = group 1 compared with 2, 3 and 4; f $p < 0.05$ = group 2 compared with 4.