

Research article

Race Dynamics in Triathlon Mixed-Team-Relay Meaningfully Changes with The New Regulation Towards Paris 2024

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Abstract

Mixed-Team-Relay (MTR) triathlon is a novel Olympic discipline whose performance determinants and tactical behaviors have barely been studied. Additionally, a regulatory change has been made to the male and female relay order for the Paris 2024 Olympics. Therefore, this study aimed to determine the performance determinants and race dynamics as a function of competitive level on the new regulated MTR triathlon. Results from 129 national teams, (516 elite triathletes) across five MTR World Triathlon Series and two MTR European Championships in 2022 and 2023, were analyzed. Split times, average speeds, time behind the race leader (gap), partial and finishing positions, pack position as well as the rank positions of every segment, relay leg, and overall race were computed. Decision tree analyses were conducted as a predictive method for the overall results, and correspondence analyses were conducted to examine the relationship between the different relay legs and segments and the finishing positions. The performance of the fourth leg was the most relevant for overall result (30%), as well as the fourth running leg (16%) and the female legs performance (7%). Medallist relay teams were characterized by displaying a differential speed lower than 0.5 and 0.83 km/h, respectively, from the best-ranking athletes in the Legs 1 and 4. Furthermore, staying in the front pack after the second swimming leg showed a great relationship with achieving a medal position. New MTR triathlon rules shift race dynamics, emphasizing individual efforts in cycling and swimming, while maintaining the crucial importance of running.

Key words: Swimming, cycling, running, competition, packing, tactics.

Introduction

After its Olympic debut in Tokyo 2021, the Mixed-Team-Relay (MTR) triathlon event underwent a regulatory change by World Triathlon (2022), altering the order of male-female relay participants. Because of this, in the 2024 Paris Olympic Games, the competition will take place in the sequence of male-female-male-female unlike the previous female-male-female-male relay order. Yet, the competition distances will remain unchanged, with each leg completing a Super-Sprint triathlon distance.

Due to being a new triathlon format, only a few recent studies have investigated how MTR teams should be composed for better race results (Ledanois et al., 2023). Quagliarotti et al. (2022) and Martínez-Sobrino et al. (2023) analyzed the MTR World Championships annually hosted in Hamburg (Germany) and found that the perfor-

mance of the third relay leg (a female triathlete) was the most relevant for the overall result. Additionally, female triathletes had a greater impact on overall team performance than males (Martínez-Sobrino et al., 2023) possibly due to a higher relative contribution to the total relay time (Quagliarotti et al., 2022), as previously observed in other mixed-team-relay disciplines (Veiga et al., 2021).

However, some differences have been found between studies regarding the most crucial discipline (swimming, cycling or running) for performance in MTR triathlon. Quagliarotti et al. (2022) identified cycling as the most important predictor for overall MTR result, while Martínez-Sobrino et al. (2023) highlighted the running segments of the race. Both disciplines have been found to be decisive in other triathlon distances, with cycling presenting the best agreement with overall performance for Sprint (Olaya et al., 2021) and running for Olympic distance triathlons (Vleck et al., 2006). However, there is also a lack of consensus among researchers regarding the importance of different race segments depending on the competition distance. This may be explained by the mass-start nature of triathlon, where different tactical approaches and pacing strategies can result in each competition taking place under unique conditions and race scenarios (Smits et al., 2014; Thiel et al., 2012).

Additionally, since drafting is permitted in short-distance triathlons and packs may form during competition, triathletes could benefit from a reduced physiological cost and lower perceived effort in a drafting position during swimming, cycling and running (Chatard et al., 1998; Hausswirth et al., 1999; Zouhal et al., 2015), which undoubtedly would affect their tactical decisions. Positioning in the leading packs during the swimming and in the initial two laps of the cycling segment has been shown to have a strong relationship with achieving a better result in Olympic distance triathlon (Landers et al., 2008; Vleck et al., 2008; Vleck et al., 2006). However, in running, the drafting benefits are less than those reported in swimming and cycling (Schickhofer and Hanson, 2021; Zouhal et al., 2015). The only previous evidence on MTR triathlon suggested that being at the front of the race from the beginning seemed to be important for success in the former MTR format (Ledanois et al., 2023), without packing behaviors being addressed.

To our knowledge, no one has so far studied what are the performance determinants and the dynamics of the MTR triathlon races in the order that will be competed in

2024 Paris Olympic Games (male-female-male-female). This new regulation could affect the race performance determinants and the race tactics employed by MTR teams. Therefore, the aim of the present research was to determine the performance determinants and race dynamics as a function of competitive level on the new regulated MTR triathlon competitions. It was hypothesized that the performance of the first relay leg, the cycling segment, and being positioned in the first pack from the first relay leg would have a greater influence on the overall team performance than in the previous MTR regulations.

Methods

Participants

The results of 129 national teams that participated in all the MTR World Triathlon Series and European Championships celebrated in 2022 and 2023 were analysed. In total, data from seven events were collected including five MTR World Triathlon Series and two MTR European Championships. This represented analyzing race data of 258 female and 258 male elite triathletes ($n = 516$) from 30 different countries. Teams that dropped out of the competition or were disqualified were not included in the analysis (14 teams). The race distances for all mentioned events ranged from 270 to 300 m in the swimming segment, from 6.6 to 8 km in the cycling segment, and from 1.6 to 1.9 km in the running segment. Water temperature ranged from 13.7 °C to 28.8 °C, therefore, wetsuit was just allowed in two races. All the study data were publicly available in the World Triathlon database (World Triathlon, 2023) so informed consent was not required.

Measures

The split times (in seconds) of each discipline (swimming, cycling and running), of each relay leg (first to fourth), and the overall relay team time were collected from each event race results. Average speeds (m/s for swimming and km/h for cycling, running and leg performance) were calculated based on the split times and the official distances of each competition, whereas differential speeds (m/s or km/h) from the fastest rank were used to standardize race conditions and distances. Partial and finishing positions of the relay teams were also collected, as well as rank positions for each team within each relay leg and discipline. Based on the influence of distance between individuals on the drafting effect, a time gap exceeding 1 second for the cycling and running segments (Allebosch et al., 2020; Hanley, 2016), and a gap exceeding 5 seconds for the swimming segment (Silva et al., 2008) were considered to define race packing through the race.

Statistical analysis

Correspondence analyses (CA) were performed to evaluate the relationship between the final position (categorized into groups: group 1 corresponds to the Top 3; group 2 from the 4th to the 10th position, and group 3 the remaining finishing positions) with the rank and the pack position in the different segments (12 segments). Therefore, 24 graphs were calculated and the same analysis was carried out with the medallists (gold, silver, and bronze), resulting in another 24

graphs. These 48 models were reduced to two dimensions and graphically represented in R^2 , where 100% of original information was retained in the process of dimension reduction through this technique. Furthermore, a calculated weighted average was performed to illustrate the dynamics of the race considering both the number and the density of the packs in each segment and relay leg.

In addition, classification or decision tree models were performed to examine the influence of the speed differential of the fastest rank, the time behind the race leader (gap), and the pack position at the end of each segment on the overall performance of the relay team. This approach assigns the previous classification variable for each relay leg (Leg 1, 2, 3 or 4), discipline (swimming, cycling and running) and gender (male or female) to a group depending on their final position: medallists (Top 3), finalists (4th to 10th) and the remaining finishing positions. Initially, a random sub-sample comprising 70% of the data was chosen to generate each of the projected trees (training sample). The remaining 30% of the sample was then employed for validation purposes, involving the computation of the confusion matrix and precision coefficient (accuracy). Six trees were generated, and the confusion matrix (based on the validation sample) along with the precision coefficient were computed. Only models with accuracy rated above 65% were retained. Statistical analyses were performed using R Package (v. 4.1.2 for Windows).

Results

The descriptive values of the average speeds during the MTR events of the 2022 and 2023 World Triathlon Series and European Championships revealed how triathletes in Legs 1 and 2 reached the maximum speeds in each segment (see Table 1). The distribution of the race packs illustrates (Figure 1) a tendency for a greater pack size in swimming compared to the previous running leg. During the initial running leg, approximately 15% of all triathletes were in the first pack. However, triathletes regrouped during the subsequent swimming leg, with 38% of the triathletes now in the lead group. From then on, there was a tendency for a greater number of packs in the third and fourth legs, compared to the first and second.

CA revealed that winning relay teams exhibited notably high associations with securing the top rank in the cycling and running segments of the third relay leg, as well as achieving a TOP 2 position in the fourth running leg (Figure 2). Strong associations were found between the medallist finishing position and achieving TOP 5 run splits in Leg 2, as well as excelling in the TOP 3 run splits in Legs 3 and 4. Additionally, medallists also recorded the best or second-best bike split in the third and fourth relay legs (see Supplementary Figure 1).

Furthermore, significant associations were discovered when examining the pack number in each segment and the final outcome (Figure 3 and Figure 4). Specifically, relay teams winning gold or silver medal exhibited a strong association with being in the first pack after the third swimming leg, while bronze medallist were associated with the second pack (Figure 3). Subsequently, being in the first pack during the fourth swimming and cycling legs was

highly correlated with winning the relay. Similarly, the same association was found for securing the second and third positions in the fourth cycling leg and the final ranking, respectively (see Supplementary Figure 2). From the second swimming leg, the athlete's position within the pack emerged as a crucial factor in determining their status as a medallist or finalist (Figure 4a). Nevertheless, it is at the end of the second running segment that being in one of the top three packs will determine the achievement of medals. From this point onward, all subsequent segments exhibited a strong association between being in the first pack and earning a medal (Figure 4b and Figure 4c).

In the classification trees, the models were estimated from the training sample, and the accuracy was higher than 65.51% in all the models, some of them up to 86.20%, indicating the models' high predictive capability. The performance in the relay Legs 4 and 1 held the highest relative importance (41% and 32%, respectively) for

performance, followed by Leg 2 (16%) and Leg 3 (12%). Medallist relay teams (G1) were characterised by displaying a differential speed lower than 0.5 and 0.83 km/h respectively, from the best-ranking athletes in the Legs 1 and 4. Conversely, finalist teams (G2) exhibited a similar trend, but with a higher differential speed in Leg 1 (see Figure 5b). Additionally, finalist teams (G2) showed differential speeds with the fastest athlete higher than 0.83 km/h in the Leg 4 and lower than 0.6 km/h in the Leg 1, whereas G3 teams presented differential speeds greater than 0.6 km/h in Leg 1.

In addition to the relay legs, the specific performance in the running segment in Legs 4 and 3 emerged as the most influential predictors of overall performance (16% and 12%, respectively). If the speed of Run 3 and Run 4 was at most 1 km/h or 1.3 km/h slower than, respectively, the fastest female triathlete in Run 4 or the fastest male triathlete in Run 3, there was a high probability of

Table 1. Swimming, cycling, running and leg speeds of participants in the 2022 and 2023 Triathlon Mixed-Team-Relay World Triathlon Series and European Championships as a function of their final ranking, legs, and sex.

	Swim (m/s)	Cycle (km/h)	Run (km/h)	Leg (km/h)
Medallists	1.27 ± 0.10	39.60 ± 2.68	19.23 ± 1.67	25.70 ± 1.76
Finalists	1.26 ± 0.11	39.01 ± 2.85	18.63 ± 1.82	25.25 ± 1.87
Finishers	1.24 ± 0.10	38.07 ± 3.61	18.12 ± 1.88	24.74 ± 1.92
Leg 1	1.36 ± 0.07	41.23 ± 2.07	19.89 ± 1.46	26.85 ± 1.27
Leg 2	1.19 ± 0.06	36.95 ± 2.20	17.33 ± 1.28	23.79 ± 1.22
Leg 3	1.29 ± 0.07	40.23 ± 2.00	19.57 ± 1.39	26.17 ± 1.28
Leg 4	1.17 ± 0.06	36.12 ± 2.06	17.16 ± 1.34	23.39 ± 0.95
Males	1.33 ± 0.08	40.73 ± 2.10	19.74 ± 1.43	26.52 ± 1.32
Females	1.18 ± 0.06	36.56 ± 2.17	17.25 ± 1.31	23.60 ± 1.11

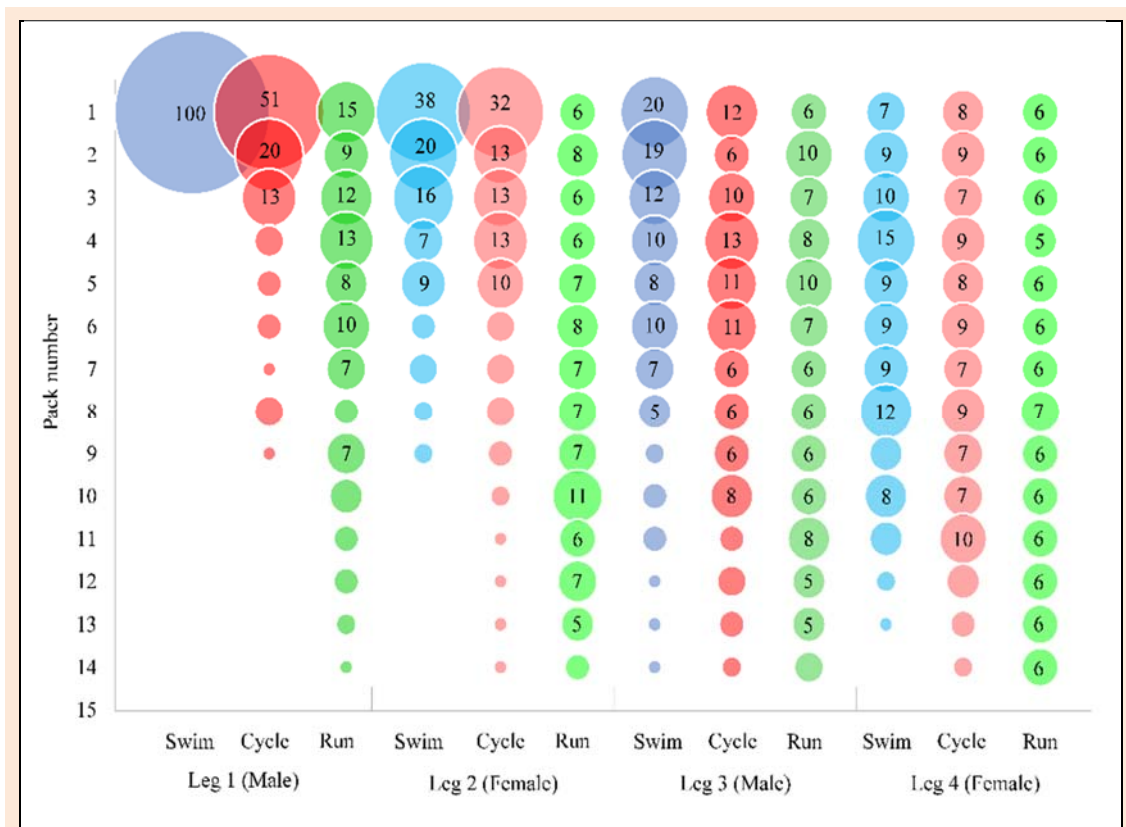


Figure 1. Graphic representation of the race packs during different segments and legs of the 2022 and 2023 Triathlon Mixed-Team-Relay World Triathlon Series and European Championships. Note: The label and size of the bubble represents the percentage of athletes in the pack relative to the total number of triathletes. The pack number indicates the position. Relative to the number of teams competing, packs comprising less than 8% of the total triathletes would represent an athlete competing solo.

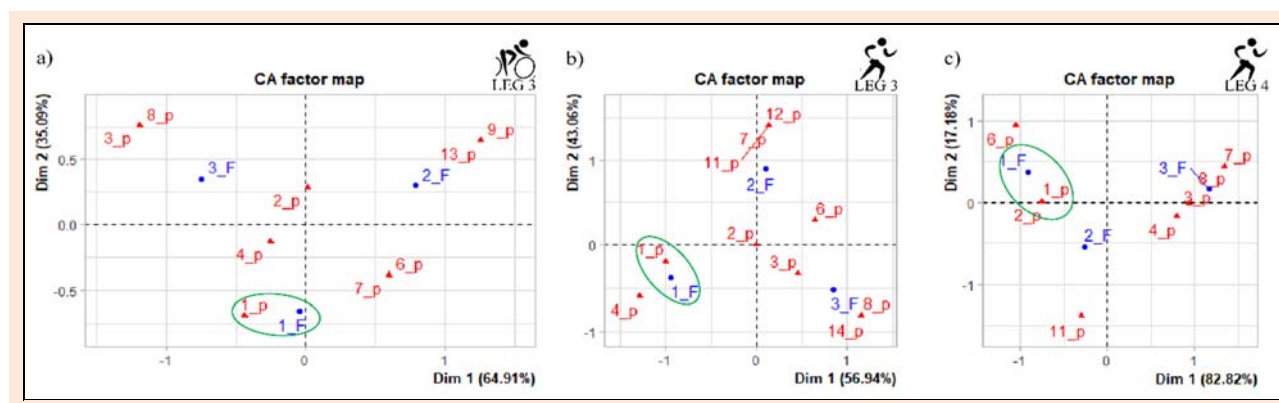


Figure 2. Correspondence analysis (CA) between final position (represented by blue dots) and the split time ranking (red dots) in a) the third cycling leg and the b) third and c) fourth running legs of the 2022 and 2023 Mixed-Team-Relay World Triathlon Series and European Championships.

achieving a medal (G1). However, the swimming and cycling performances of some other relay legs also seemed to exert notable relevance in the competition result (Figure 5a). In case of securing finalist position (G2), the cycling speed of Leg 2 should be no more than 2.1 km/h below the maximum for that leg. Concerning gender, women's performance proved to be more relevant to the final outcome (7%) compared to men (1%), considering the aggregation of all performance variables (relay legs, segments and gender).

The athlete's position within the race packs did not appear to play a decisive role from the beginning of the race to the second swim leg. However, from this segment, as more packs were formed (Figure 1), remaining within an advanced pack became increasingly relevant to secure a better final position. Regarding the gap time behind the leader, exceeding 2 m 13 s after the swimming segment of relay leg 4 could result in teams not achieving finalist positions (G3). Conversely, when the gap time was less than 55 s after the cycling of the last relay leg, teams could still win a medal (G1).

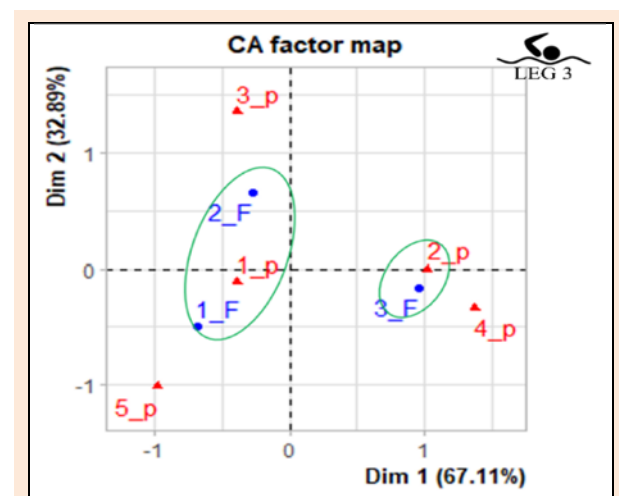


Figure 3. Correspondence analysis (CA) between classifying first (1_F), second (2_F), and third (3_F) (represented by blue dots) and the pack position (red dots) in the third swimming leg of the 2022 and 2023 Mixed-Team-Relay World Triathlon Series and European Championships.

Discussion

The present study aimed to determine the importance of different relay legs, sports disciplines and pack position in teams' overall performance during the triathlon MTR World Triathlon Series and the European Championships from 2022 to 2023. In 2022, World Triathlon modified the regulations for these events in terms of the position of male and female triathletes within the relay legs. Since then, no evidence has been provided on the race performance determinants in this discipline. According to our results, the running segment, the fourth relay leg as well as the females relay legs were the most important for the overall MTR performance, with race packing also having a real impact on race result.

The performance of Leg 1 (male triathlete) has been found to be very relevant, explaining 21% of the overall MTR result. This was also observed (32% of predicting ability) when the importance of the relay leg was analysed in terms of the medallists, finalists, or finishers teams. Teams whose first relay leg was not able to perform close to the race leader (<0.5 km/h), would be out of chance of being a medallist (see Figure 5b). This is in contrast to what was found with the previous MTR regulation where the first relay leg was performed by a female triathlete, as the impact on the final result was only 3% (Martínez-Sobrino et al., 2023). This may be explained by the difficulties by female triathletes to bridge the gaps during cycling (Piacentini et al., 2019). With the current regulation, if the first relay leg by the male triathlete is hand over with a large gap time from leaders, it is very probable that the female triathlete of the second leg will not be able to bridge the gap and will lose any winning or medal chances for that team. This is the reason why the pack position after the second swimming leg was also very relevant to the overall result and it showed a strong association with being medallist or finalist (Figure 4a), as previously observed in Olympic distance with the pack attained at the beginning of the cycling segment (Vleck et al., 2008). In fact, women placed in leading packs at that race stage probably benefit from drafting during the swimming and cycling segments (Chatard et al., 1998; Hausswirth et al., 1999) and collaborated in the bike pack to increase the gap with the followers.

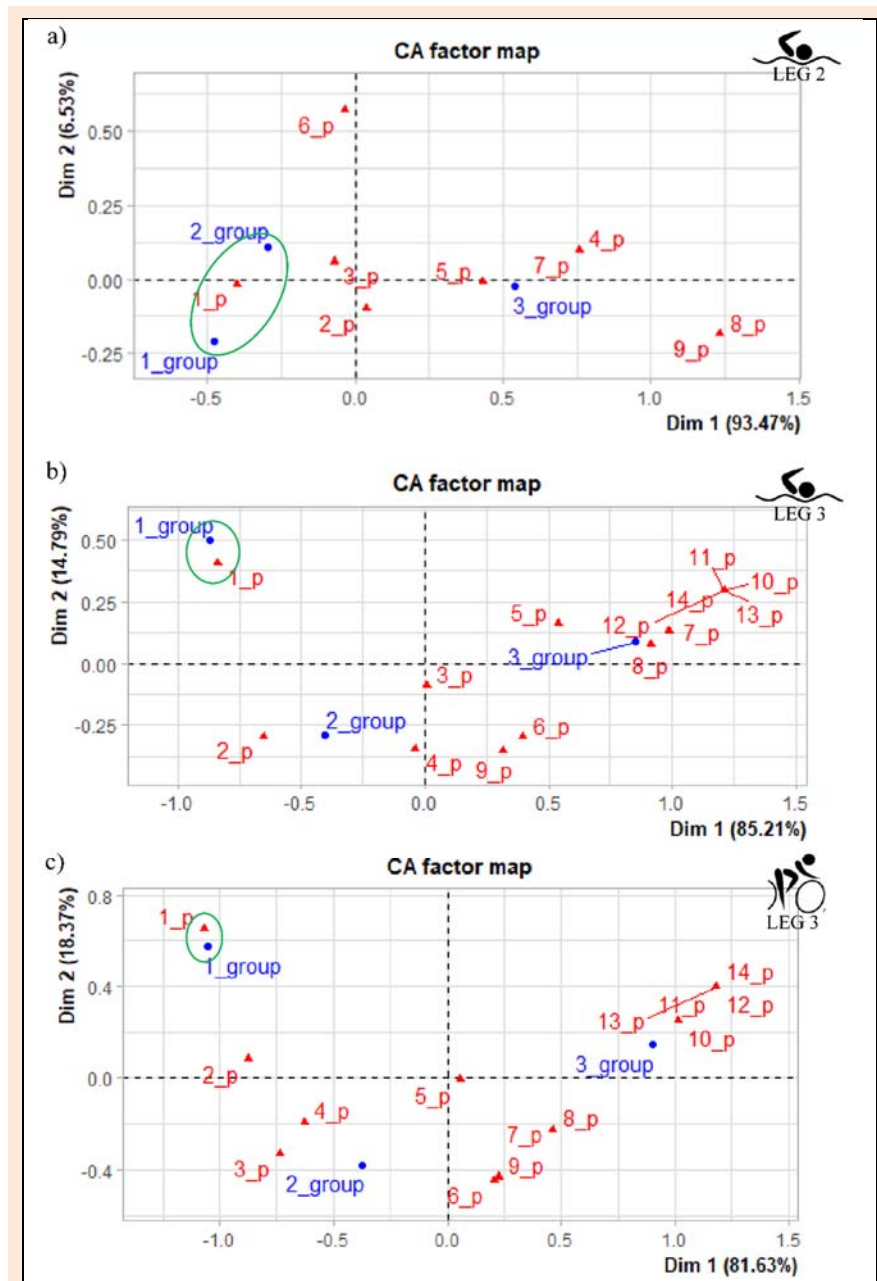


Figure 4. Correspondence analysis (CA) between classifying medallist (G1), finalist (G2), and those finishing above 10th position (G3) (represented by blue dots) and the pack position (red dots) in a) the second and b) the third swimming leg and c) the third cycling leg of the 2022 and 2023 Mixed-Team-Relay World Triathlon Series and European Championships.

Nevertheless, the performance of Leg 4 (female triathlete) was the best predictor of the final MTR result (30%). This is in a clear contradiction with previous MTR regulations where Leg 3 (female) was the most important leg (17%) and Leg 4 (male) the least relevant (1%) (Martínez-Sobrino et al., 2023) but it somehow highlights the importance of the second women's relay leg (Leg 3 before 2022 and Leg 4 from 2022 onwards) regardless of the race regulations. Since the competition packing is highly segmented at the beginning of Leg 4 (see Figure 1), and medallists race solo at that race stage (no drafting), the individual capacity of the triathlete rather than other tactical race factors (packing, drafting...) could explain their final performance (Ledanois et al., 2023). In fact, our results showed how medallists achieved the best time splits in the fourth cycling and running leg, and also how the speed

differential with the fastest rank triathlete was lower than 0.5 km/h in the leg 4, with a gap time from the race leader at the beginning of the last run leg lower than 55s. This race behaviour, where medals are disputed in the last race segment or split, has also been described in other endurance mass start disciplines, where rewards are based on finishing position rather than finishing times (Thiel et al., 2012). Overall, the female relay legs with the new MTR regulation presented a greater influence on race performance, which coincides with results from previous regulations (Martínez-Sobrino et al., 2023) and in other MTR sport disciplines (Veiga et al., 2021). Of course, the slower average speed of female athletes (see Table 1) and also their greater contribution to the total team relay time compared to their male counterparts (Piacentini et al., 2019; Quagliarotti et al., 2022) could explain this specific outcome.

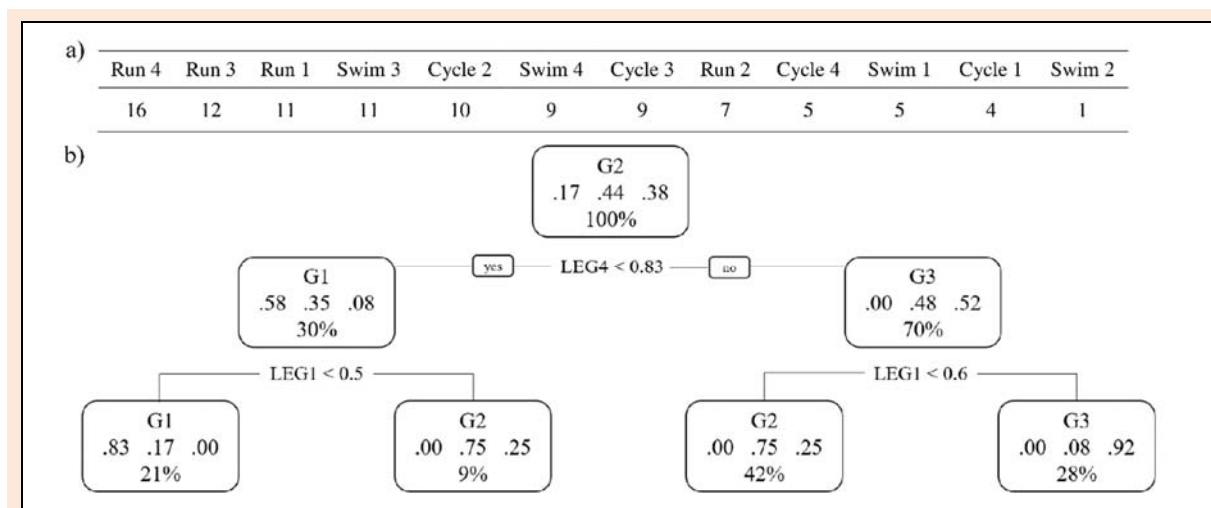


Figure 5. Decision tree classification for a) the segment importance (%) and b) the differential speed (km/h) with the best-ranking legs in the 2022 and 2023 Mixed-Team-Relay World Triathlon Series and European Championships. Note: The decision tree classifies medallist teams, finalists and above 10th position as G1, G2 and G3, respectively.

According to the race segments, running performance was the most relevant segment in the MTR triathlon (11% compared to 9% in the cycling and swimming segments). Strong associations were detected between becoming a medallist or race winner with achieving the best ranks in the running segments of Legs 2, 3 and 4. This is in line with previous evidence in Olympic distance triathlon (Gadelha et al., 2020; Noble and Chapman, 2018; Ofoghi et al., 2016) but it was not in agreement with a greater importance of cycling performance in Sprint and MTR triathlons (Olaya et al., 2021; Quagliarotti et al., 2022). However, the relevance of each MTR discipline was more balanced (see Figure 5a) than with the previous regulation, where running explained 32% of the overall MTR performance (Martínez-Sobrino et al., 2023). The earlier segregation of the race in multiple packs with the new regulation, due to males performing Leg 1 (see Figure 1), probably reduced the benefits of drafting in the swimming and cycling disciplines and highlighted the individual performance of triathletes in each different race segment (Ledanois et al., 2023). Indeed, a better performance in the second cycling leg, which can be attributed to staying within larger cycling packs in leading positions and maintaining higher speeds (Olds, 1998), showed to be crucial for attaining a medallist position along with achieving the best bike splits in Legs 3 and 4. Regarding swimming, the pack positioning for Legs 2, 3 and 4 was strongly related to the medal positions but no associations with race performance were found for the swimming ranking. This probably highlighted the importance of remaining in the front swimming packs (Landers et al., 2008) despite the low relative duration of the swimming leg (Quagliarotti et al., 2022) and the small time differences marked in 300 m in the analysed competitions.

According to these results, teams competing in MTR should consider that, in case their line up is not composed by four competitive legs, their stronger male and female athletes should be placed in Legs 1 and 2. Furthermore, their individual performance in the swimming, cycling, and running disciplines should be balanced. This would ensure that the team can remain within the leading

race groups for a significant portion of the race, thus maximizing the benefits of drafting with the race leaders. On the other hand, teams who have four competitive athletes should place those who are better able to perform on their own in Legs 3 and 4. Of course, these recommendations should be interpreted in relation to the different race scenarios and environmental factors (e.g., wind, air temperature, water temperature, humidity) that could have influenced such analysis. In addition, average speeds of the different relay legs should be interpreted with caution due to the lack of available information regarding the distances of the transitions and the finish line sections. Further studies are needed to gather performance data in MTR competitions to understand the competitive demands and how race dynamics may influence them.

Conclusion

The results of the present study suggested that the new World Triathlon regulations meaningfully modify race dynamics in MTR triathlon. Participants were divided into several packs from the first race leg performed by a male triathlete and, therefore, they spent a greater race contribution in the form of solo efforts. Consequently, a greater importance of the individual performance during cycling and swimming segments was detected compared to the previous regulations, although the running performance remained the most decisive discipline, with medallists recording the best running splits.

Acknowledgements

The authors declare that there are no conflicts of interest. The experiments comply with the current laws of the country where they were performed. The data that support the findings of this study are available on request from the corresponding author.

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Key points

- The new male-female-male-female order meaningfully changes race dynamics in triathlon Mixed-Team-Relay.
- The performance of the first and fourth relay legs and being positioned in the first pack after the initial relay leg are key factors for achieving medallist positions.
- A greater importance of the cycling and swimming segments was detected compared to the previous regulation. However, running performance remained the most decisive discipline, with medallists recording the best running splits.

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