

Strategic analysis of teams in the triathlon mixed relay at world circuit stages events

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Abstract

This study examined the impact of team composition strategies in the Triathlon Mixed Relay, analyzing data from the Sunderland and Hamburg stages of the 2023 World Triathlon Mixed Relay Championship and World Triathlon Mixed Relay Series. Split times for swimming, cycling, running, transitions, and overall team performance were collected. Athlete and team performances were summarized using descriptive statistics (means and standard deviations) while data normality was assessed with the Shapiro-Wilk test. To compare times across different segments and transitions, a repeated measures ANOVA followed by Tukey's post hoc test was performed. Simple linear regressions were used to examine the impact of each segment and transition on total performance, and standardized estimates were calculated to compare the relative importance of each independent variable. The results showed significant differences between disciplines ($p < .001$), with cycling contributing the largest portion of the total time (49–52%), followed by running (24–27%) and swimming (17–20%). Pearson correlations indicated a strong association between cycling and running with overall time in both events. Regression analyses revealed a greater impact of cycling on total time in Sunderland, while running was more influential in Hamburg. Furthermore, athlete order analysis showed that A1 and A2 consistently outperformed A3 and A4, suggesting a deliberate team strategy in athlete placement. All statistical analyses were performed using JAMOVI software (version 2.3.28), and the data used are publicly available, containing no confidential information. These findings highlight the importance of tailoring strategies to the specific course and athlete order, supporting the development of more effective approaches in international mixed relay competitions.

Keywords: sports performance, triathlon, team strategy, quantitative analysis, disciplines

Introduction

Triathlon is a sport that combines swimming, cycling, and running, has its origins in ancient athletic practices (Bentley et al., 2002; Sousa et al., 2021). Over time, standardized competition distances have been established (Cuba-Dorado et al., 2022; Olaya et al., 2021), including standard, sprint, super sprint, and mixed team relay (MTR). The standard distance consists of 1.5 km of swimming, 40 km of cycling, and 10 km of running. MTR, which debuted in the Olympic program in Tokyo 2020, features flexible distances adapted to local conditions, typically 250–300 m swimming, 5–8 km cycling, and 1.5–2 km running (Bentley et al., 2002; Van Schuylenbergh et al., 2004; WTCR, 2024).

Since 2022, athlete order in MTR has been standardized, starting with a male athlete, followed by a female, another male, and concluding with a female athlete (WTCR, 2022). In addition to disciplines, distances, and athlete order, transitions are critical. Transition 1 (T1) marks the switch from swimming to cycling, and Transition 2 (T2) from cycling to running (Cejuela et al., 2013; Olaya et al., 2021; Vleck & Alves, 2011). To be competitive in MTR, teams must strategically select shortdistance triathletes, prioritize swimming and cycling skills, and assign athletes 1 and 2 to perform in groups, while athletes 3 and 4 should excel in time-trial style racing (Veiga et al., 2023; Ledanois et al., 2023; Martínez-Sobrino et al., 2024). Moreover, athlete 3 shows a stronger relationship with final outcomes (Quagliarotti et al., 2022).

Swimming typically accounts for ~15% of total race time, cycling for ~55%, and running for ~35% (Anta et al., 2007; Figueiredo et al., 2016; Piacentini et al., 2019). Findings from Quagliarotti et al. (2022) confirm these proportions but also emphasize the impact of swimming in MTR outcomes. Additional research highlights that athletes A1 and A2 are generally the fastest, and the top teams show high correlations in cycling and running during the third relay leg. Notably, the running time of the second female athlete is strongly associated with top five team performances. Furthermore, athletes in the third and fourth legs tend to have the best or second-best cycling times (Martínez-Sobrino et al., 2024).

Teams that maintain a leading group position during swimming and cycling are more likely to podium.

However, starting from the second swim leg, athlete positioning within the group becomes critical in determining medal potential. Being among the top three groups after the second running leg is decisive for podium chances. The statistical relationship is strongest for athletes 4 and 1 (41% and 32%, respectively), followed by athlete 2 (16%) and athlete 3 (12%).

This study adopts a descriptive and exploratory approach to examine stages of the global circuit, traditionally held in the same cities and significantly influencing Olympic rankings. Given the high competitive level of this Olympic discipline, this study aims to analyze and compare national team composition strategies in premier triathlon mixed relay events.

Methodology

For this study, the sample included data from the 2023 World Triathlon Mixed Relay Championship (WTMRC) and the 2023 World Triathlon Mixed Relay Series (WTMRS), which represent the main events of the international circuit and carry the greatest weight in the Olympic qualification system (*World Triathlon Mixed Relay Ranking*). The analyzed events were Sunderland (United Kingdom) and Hamburg (Germany). The Montreal (Canada) and Paris (France) stages were excluded due to the lack of data and changes in race format to duathlon (run, bike, run), ensuring the reliability of the results. The total number of teams analyzed was $N = 17$ in Sunderland and $N = 20$ in Hamburg.

Official race data were obtained from the World Triathlon website (www.triathlon.org, accessed on February 20, 2024). The collected variables included swim time, T1, bike time, T2, run time, and total time. To facilitate the analysis, athletes from each team were labeled as A1 (first athlete), A2 (second athlete), A3 (third athlete), and A4 (fourth athlete). This identification allowed for the individual assessment of each athlete's performance within the team and the identification of specific performance patterns. Athlete age data were not provided in the official dataset.

To describe the performance of teams and athletes, descriptive statistics (means and standard deviations) were used. The normality of the data was verified using the Shapiro–Wilk test, and repeated measures ANOVA with Tukey's post hoc test was conducted to compare times across disciplines and transitions.

Simple linear regression analyses were employed to examine the impact of each discipline and transition on the final race outcomes. Standardized coefficients were calculated to compare the relative importance of each independent variable in relation to the dependent variable (total time). All statistical analyses were conducted using JAMOV software (version 2.3.28). It is important to note that the data used are publicly available and do not involve any confidential information.

Results

The results show that 17 teams participated in the Sunderland event and twenty in the Hamburg event. The mean times for each discipline and their respective proportions of the total race time are presented in Table I. The standard deviations indicate considerable variability in the data. A repeated measures ANOVA revealed statistically significant differences across all segments ($p < .001$), which were further confirmed by Tukey's post hoc test ($p < .001$).

Table I: Descriptive statistics for the Sunderland and Hamburg races (times in seconds) and relative percentage of each segment in relation to total race time.

	Swim	T1	Bike	T2	Run	Total
Sunderland time (s)	913±4,4 ^a	232±6,57 ^b	2847±75 ^c	111±4,6 ^d	1282±39 ^e	5377±107
p-value	<0.001	<0.001	<0.001	<0.001	<0.001	
Hamburg time (s)	1005±20,8 ^a	125±5,35 ^b	2492±39 ^c	92,7±3,74 ^d	1341±33,4 ^e	5047±80,9
p-value	<0.001	<0.001	<0.001	<0.001	<0.001	
Hamburg						
Sunderland % total time	16,90%	4,29%	52,43%	2,04%	23,68%	
Hamburg % total time	19,91%	2,47%	49,37%	1,83%	26,57%	

Different letters (a; b; c; d; e) = statistically significant differences between all disciplines and transitions ($p < 0.001$); percentage of each discipline and transition relative to the total team time

Swimming showed considerable variation between stages, with a low correlation in Sunderland ($r = 0.123$) and a high correlation in Hamburg ($r = 0.798^{***}$). This contrast may indicate differences in race conditions, athlete technical level, or course characteristics influencing overall performance.

Transitions (T1 and T2) showed moderate correlations, with T1 notably displaying a positive relationship in Sunderland ($r = 0.518$) but a near zero correlation in Hamburg ($r = -0.096$). All these data can be observed in the table II. This suggests that the impact of transitions may vary depending on the race format and competitiveness among teams.

These findings highlight the importance of strategy in team composition and race planning, particularly regarding performance in the cycling and running segments, which consistently showed the strongest associations with final results.

Table II – Correlation between segments and total time in Sunderland and Hamburg.

Segment	Sunderland(r)	Hamburg(r)	Mean(r)
Swim → Total***	0,123	0,798***	0,461***
T1 → Total***	0,518*	-0,096	0,211***
Bike → Total***	0,931***	0,841***	0,886***
T2 → Total***	0,351	0,593***	0,472***
Run → Total***	0,778***	0,861***	0,819***

Correlation (r) between segment times and the total team time in the Sunderland and Hamburg stages of the 2023 World Triathlon Mixed Relay Series. The "Mean (r)" column represents the average correlation across both events. * $p < .05$, ** $p < .01$, *** $p < .001$

Simple linear regression performed with the summed segment times for both the Sunderland and Hamburg stages showed a perfect model fit ($R = 1.000$; $R^2 = 1.000$), indicating that 100% of the variability in total time can be explained by the predictor variables: swim time, T1, bike time, T2, and run time.

In Sunderland, the regression coefficients demonstrate each segment's contribution to the total time. Cycling ($\beta = 1.003$, $p < .001$) had the highest standardized influence (β std = 0.7014), suggesting it has the greatest impact on overall performance. Running ($\beta = 1.008$, $p < .001$) also showed a significant influence (β std = 0.3673). Despite their shorter duration, the transition times also contributed significantly to the team's total time, with coefficients close to 1.

Another noteworthy finding is the negative intercept coefficient (-58.222), which may indicate a bias in the model estimation, suggesting that the predicted total time is lower than the direct sum of individual segment times. This could be due to rounding errors in the official data sheets.

In Hamburg, the regression coefficients again show that cycling ($\beta = 1.003$, $p < .001$) had the highest standardized influence (β std = 0.4842), followed closely by running ($\beta = 1.004$, $p < .001$; β std = 0.4140). The transition times also made a significant contribution, with T2 (β std = 0.0528) appearing slightly more relevant than T1 (β std = 0.0408).

As in the Sunderland analysis, the negative intercept coefficient (-48.222) may suggest a similar estimation bias, again potentially due to rounding in the official timing data.

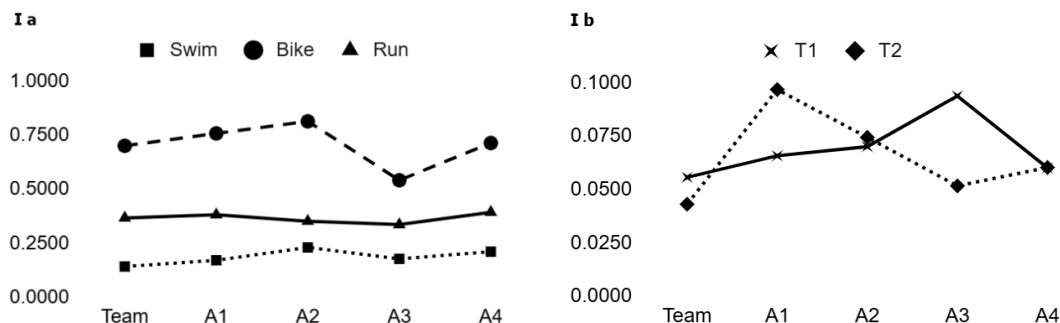


Figure I a – Standardized estimates from the Sunderland stage: comparison between teams and (A1, A2, A3, and A4).

Figure I b – Standardized estimates for swim, bike, and run segments (2a), and transitions T1 and T2 (2b).

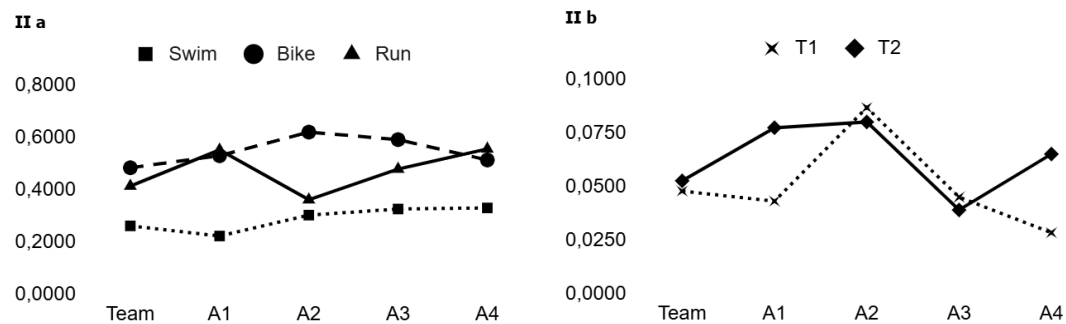


Figure II a – Standardized estimates from the Hamburg stage: comparison between teams and athletes (A1, A2, A3, and A4).

Figure II b – Standardized estimates for swim, bike, and run segments (2a), and transitions T1 and T2 (2b).

Analysis of Athletes 1, 2, 3, and 4 from Each Team

Descriptive analysis of the Sunderland and Hamburg stages shows that the first two athletes (A1 and A2) are generally faster compared to athletes A3 and A4. Male athletes tend to perform faster than female athletes. In Sunderland, the standard deviation (SD) tends to increase as the race progresses, particularly when comparing female athletes (A2 and A4) to male athletes (A1 and A3), suggesting greater variability in performance later in the race. All the data can be observed in Tables III and IV.

Table III: Descriptive analysis of individual athletes A1, A2, A3, and A4 in the Sunderland stage (times in seconds).

	Swim	T1	Bike	T2	Run	Total
A1 mean	207 ± 4,27	54,4 ± 1,80	665 ± 18,5	27,2 ± 2,19	290 ± 9,34	1241 ± 24,6
A2 mean	241 ± 7,40	59,8 ± 2,60	735 ± 26,9	28,9 ± 2,66	332 ± 11,5	1296 ± 33
A3 mean	217 ± 6,41	56,5 ± 3,45	673 ± 20,4	25,5 ± 1,62	295 ± 13,3	1265 ± 38
A4 mean	246 ± 9,06	61,4 ± 2,69	774 ± 30,9	29,5 ± 2,21	366 ± 17,3	1475 ± 43,2

Table IV: Descriptive analysis of individual athletes A1, A2, A3, and A4 in the Hamburg stage (times in seconds)

	Swim	T1	Bike	T2	Run	Total
A1 mean	231 ± 5,26	29,7 ± 1,17	579 ± 12,7	22,1 ± 1,74	307 ± 13,1	1167 ± 23,8
A2 mean	263 ± 6,77	32,5 ± 1,85	649 ± 13,6	23,9 ± 1,68	349 ± 8,02	1316 ± 22,3
A3 mean	243 ± 9,29	30 ± 1,48	603 ± 17,8	22 ± 1,08	316 ± 14,2	1213 ± 29,8
A4 mean	268 ± 9,65	31,4 ± 1,31	661 ± 15	24,7 ± 2,3	368 ± 16,5	1352 ± 29,6

Simple linear regressions performed for athletes in the same order (A1, A2, A3, and A4) in the Sunderland and Hamburg stages revealed perfect model fits ($R = 1.000$; $R^2 = 1.000$), indicating that the race segments fully explained the variability in individual total time.

In the Sunderland stage, cycling consistently showed the greatest impact across all positions, with A1 and A2 standing out (standardized $\beta = 0.76$ and 0.81 , respectively). Running appeared as the second most influential factor, particularly for A1 and A4. Transitions and swimming had a smaller impact.

In contrast, in the Hamburg stage, running had a greater influence for A1 and A4 (standardized $\beta = 0.55$ and 0.56), while cycling remained the main determinant for A2 and A3. Swimming also had a relevant influence, especially for A2 and A3, suggesting strategic differences across athlete order and race stages.

These findings highlight the importance of strategically placing athletes within the team, assigning specific profiles to each relay leg. The combination of cycling and running was particularly determinant for overall performance, especially for the athletes starting and finishing the relay. All these data can be observed in the table V.

Table V: Standardized estimates (β std.) of race segments by athlete order in the Sunderland and Hamburg stages.

Stage	Athlete	Swim	T1	Bike	T2	Run
Sunderland	A1	—	0.90	0.76	1.08	0.38
	A2	0.23	—	0.81	—	0.35
	A3	—	—	0.54	1.21	0.34
	A4	—	—	0.74	—	0.39
Hamburg	A1	0.22	—	0.53	—	0.55
	A2	0.30	1.05	0.62	1.06	0.36
	A3	0.33	—	0.59	1.08	0.48
	A4	—	—	0.51	—	0.56

Discussion

The descriptive analyses showed that Triathlon Mixed Relay (MTR) races follow the same proportional distribution observed in longer races: swimming accounts for approximately 15% of the race, cycling ~50%, and running ~35% of the total race time (Anta et al., 2007; Figueiredo et al., 2016; Piacentini et al., 2019). The results of this study highlight the importance of strategically segmenting teams in MTR, emphasizing the relevance of the disciplines that contribute most to total time—cycling and running—for final performance. In both analyzed stages, athletes A1 and A2 showed superior performances, supporting previous findings that emphasize the advantage of starting the race with faster and more experienced athletes who are able to race in packs and establish a favorable pace for the team (Quagliarotti et al., 2022). This initial strategy can be decisive in keeping the team in a competitive position for the subsequent legs.

In the Sunderland stage, cycling proved to be the main determinant of the teams' total time, followed by running. The high correlation between cycling and total time reinforces its strategic centrality. In Hamburg, however, running became the more influential discipline, especially among athletes A1 and A4, suggesting that race context and course profile can alter the key performance determinants. Recent studies also highlight this variability, showing that performance in the final segment—particularly the fourth athlete's run—can be decisive for podium finishes (Martínez-Sobrinho et al., 2024).

Additionally, new predictive models indicate that the third athlete in the relay plays a critical role in the final result, with an emphasis on the cumulative impact of cycling throughout the race (Veiga et al., 2023). These findings support the idea that athlete order should be carefully planned, considering not only gender and specialty but also the ability to maintain or regain positions in highly competitive scenarios.

In Sunderland, T1 showed a moderate correlation with total time, while in Hamburg, this influence was almost negligible. This variation reinforces that, despite their shorter absolute duration, transitions can play a decisive role, especially in races with closer team standings.

Another important point is the relationship between female performance and final team placement. Veiga et al. (2023) found that the performance of female athletes—particularly the third athlete in the relay (formerly the "dormato" leg)—has a statistically significant influence on MTR race outcomes. In our study, athletes A2 and A4, who are necessarily women, showed greater variability in their times, especially in the running segment. This fluctuation can compromise team consistency and, consequently, negatively affect final placement. Investments in pacing and endurance strategies specific to female athletes could therefore help reduce this variability and optimize overall team performance.

Additionally, the study by Ledanois et al. (2023) reinforces the importance of intermediate positions in race dynamics. Their findings indicate that from the second cycling athlete onward, there is a growing association between staying in the leading pack and the likelihood of medaling. In the present study, it was observed that teams with A2 and A3 athletes posting lower cycling times tend to remain in the lead group, which favors more aggressive tactical decisions for the final athlete. This suggests that strategic planning should consider these athletes' ability to sustain high paces in decisive segments, especially on more competitive courses.

From a methodological perspective, linear regressions revealed high standardized coefficients and R^2 values equal to 1, which suggests overfitting of the models. While a perfect fit may reflect data precision, it also indicates the need for cross-validation with other stages and years to ensure the robustness of the findings.

Conclusion

The results highlight the relevance of adopting specific strategies for each stage of the World Triathlon Mixed Relay Series (WTMRS) and World Triathlon Mixed Relay Championship (WTMRC). In Sunderland (2023), the performance of athletes A1 and A2 was decisive for the final team result, with cycling standing out as the primary determinant of performance. In contrast, in Hamburg (2023), running especially for athletes A1 and A4 showed the highest correlation with team performance.

Another important finding is that as the relative proportion of swimming and running increases, the statistical impact of cycling tends to decrease. This insight may be useful in defining athlete order and selecting the most appropriate profiles for each team position.

From a practical standpoint, the data reinforce the importance of cycling in determining overall time, suggesting that strategies aimed at optimizing this segment may be crucial. Additionally, transition times often underestimated also showed significant impact and should be considered in both training and competition strategies.

Despite the high variance explained by the models (R^2 values close to 1), caution is warranted, as this may indicate potential overfitting. Therefore, it is recommended to validate these models with new datasets. Finally, the differences observed between the analyzed stages emphasize the need for individualized strategies in mixed relay events. Given the high level of competition and the balance between teams, building a performance history by stage may be a valuable tool for tactical and technical planning in WTMRS and WTMRC competitions. These findings provide a solid quantitative foundation for future analyses and contribute to a better understanding of the factors influencing performance in team-based triathlon events.

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