Journal of Human Kinetics volume xx/xxxx, x–x DOI: 10.5114/jhk/220529
Section III – Sports and Physical Activity

Influence of Triathlon Segments and Transitions on Elite Performance by Distance and Sex

by
Jesús Martínez-Sobrino [1], Jesús Santos del Cerro [2], José María González-Ravé [3], Santiago Veiga [1,]*

Although previous studies have examined how the triathlon segments influence overall performance, how both segments and transitions differ by sex and across short-course distances, including the Super-Sprint, remains largely unknown. This study analysed how triathlon segments impacted overall performance of elite short-course triathletes, considering sex, race distance, and the performance level. Results from 113 World Triathlon Series (2017–2024), including Super-Sprint, Sprint, and Olympic races, were analysed for elite female and male triathletes (n = 5051). Split times were normalised to a 0–100 score and analysed using general linear models and decision tree analyses. Running performance showed the strongest associations across all distances, with β values ranging from 0.13 to 0.39 for males and 0.07 to 0.23 for females, for Super-Sprint to Olympic races, respectively. Running also showed the highest contribution to prediction capacity for Top-10 finishers. Although cycling's predictive capacity increased with distance, it remained lower than swimming for female athletes. Transition times, especially transition 1 (T1), had a notable influence on final positions in Sprint and Super-Sprint events, particularly among females (β = 0.13 and 0.07, respectively), but had minimal impact in the Olympic distance. Transition 2 (T2) also contributed to Sprint performance in both sexes (β = 0.05). Our findings reveal that, as competition distance increases, cycling and running become more crucial, with running being the most decisive factor for both sexes. T1 performance is more influential for female triathletes, especially in shorter distances, whereas swimming has minimal impact on overall results, except for Top-10 female finishers.

Keywords: *swimming; cycling; running; transitions; competition analysis*

Introduction

Triathlon is a multi-sport discipline that combines swimming, cycling, and running, with each segment connected by transition areas where athletes change gear and prepare for the next stage (World Triathlon Competition Rules, 2024). It is considered an endurance sport, with race distances that vary significantly (World Triathlon Competition Rules, 2024). The shortest event, the Super-Sprint (250–300-m swim, 5–8-km bike, and 1.5–2-km run), typically takes around 20 minutes (Quagliarotti et al., 2022), while the longest, the IRONMAN® (3.8-km swim, 180-km bike, 42-km run), can take up to 8 hours for professionals (Barbosa et al., 2019). Short-course professional triathletes compete in the World Triathlon Series (WTS), a global competition circuit featuring the Super-Sprint distance, conducted in an eliminator format where athletes advance through heats, semi-finals, and finals, as well as the Mixed-Team Relay (MTR) (World Triathlon Competition Rules, 2024). Nevertheless, the WTS is primarily composed of Sprint (750-m swim, 20-km bike, 5-km run) and Olympic distance (1.5-km swim, 40-km bike, 10-km run) events.

Although some studies have explored which segment is most critical for overall results in the WTS triathlon (Gadelha et al., 2020; Olaya et al., 2021; Piacentini et al., 2019; Sousa et al., 2021), no

[1] *Departamento de Deportes, Facultad de Ciencias de la Actividad Física y del Deporte (INEF), Universidad Politécnica de Madrid, Madrid, Spain.*
[2] *Department of Statistics, University of Castilla-La Mancha, Toledo, Spain.*
[3] *Sports Training Laboratory, Faculty of Sports Sciences, University of Castilla-La Mancha, Toledo, Spain.*
* Correspondence: santiago.veiga@upm.es

research has been conducted for the Super-Sprint distance due to its limited number of competitions and a unique heat elimination format in which a reduced field of athletes competes in multiple rounds with progressive eliminations. Only one study has analysed split times in junior and youth events in the 2022 World Triathlon Continental Cups and Championships (Espejo et al., 2024), finding that running was the most critical segment for success, with medallists consistently staying within the top-8 throughout the race for both men and women. However, two studies on Super-Sprint triathlons with MTR formats have also found that running performance is the strongest predictor of both individual leg and overall relay results (Martínez-Sobrino et al., 2023, 2024), while another has highlighted the importance of swimming and cycling (Quagliarotti et al., 2022). In Sprint distance triathlons, cycling has been shown to be the most important segment for overall results in WTS events (Olaya et al., 2021; Sousa et al., 2021). This was observed from 2012 to 2019 using performance indicators based on the winner's time (Olaya et al., 2021), and from 2015 to 2020 by analysing the proportion of cycling time relative to the total race time (Sousa et al., 2021). Conversely, multiple studies on Olympic distance triathlons within the WTS have yielded conflicting findings regarding the most critical race segment (Gadelha et al., 2020; Olaya-Cuartero et al., 2022; Sousa et al., 2021). Overall, there appears to be a lack of consensus regarding the importance of race segments for overall performance. While some studies identify running as the most influential discipline for overall performance (Gadelha et al., 2020; Ofoghi et al., 2016; Piacentini et al., 2019), others highlight both cycling (Olaya-Cuartero et al., 2022) and swimming (Sousa et al., 2021) as key segments.

In addition, few studies have specifically examined the importance of transition phases across various competition distances in triathlon (Cejuela et al., 2013; Olaya et al., 2021; Piacentini et al., 2019). To our knowledge, no studies have been done on transitions during Super-Sprint or MTR events. One study did report, however, that transition performance showed limited concordance and a weak correlation with overall performance in Sprint distance WTS events for both men and women between 2012 and 2019 (Olaya et al., 2021). In contrast, more research has focused on the Olympic distance WTS (Cejuela et al., 2013; Ofoghi et al., 2016; Olaya et al., 2022; Piacentini et al., 2019), where findings indicate a low but still significant correlation (ranging from 0.25 to 0.36 for both male and female athletes) between time spent in transitions (Transition 1: swim-to-bike, and transition 2: bike-to-run) and overall race performance (Cejuela et al., 2013). This is likely due to the relatively short duration of transitions compared to the total competition time, which may reduce their overall influence (Cejuela et al., 2012). However, minimising time lost relative to the fastest transition split has been shown to have a stronger association with achieving a higher final position (Cejuela et al., 2013; Ofoghi et al., 2016), as well as with achieving a position close to the first athlete upon exiting the transitions (Piacentini et al., 2019). Piacentini et al. (2019) highlighted key differences between male and female triathletes. For males, success is significantly influenced by exiting T2 close to the lead athlete, as the leading positions are often decided by final sprints with differences of few seconds (Cejuela et al., 2013). In contrast, female triathletes place greater emphasis on their performance in both T1 and T2, with the ability to T1 exit being particularly crucial due to different race tactics and challenges in bridging bike packs compared to their male counterparts (Vleck et al., 2008).

Consequently, while some studies have examined the significance of segments and transitions in Olympic and Sprint distance WTS events, the use of diverse competition variables (such as split times, percentage of total time, and performance indicators) and statistical approaches, combined with the analysis of different triathletes across multiple competition years and locations, complicates the comparison of results between distances and sexes. Therefore, the aim of this study was to determine the influence of various triathlon segments on the overall performance of elite short-course triathletes, as a function of sex, race distance, and the performance level. It was hypothesized that the running segment would constitute the most significant predictor of overall performance, irrespective of race distance or sex. Additionally, it was anticipated that the relative importance of transition phases would increase as race distance shortened, with this effect being particularly pronounced among female athletes.

Methods

Participants

The results from 113 WTS events held between 2017 and 2024, covering 19 Super-Sprint, 36 Sprint, and 58 Olympic distance races were analysed. The first relay legs for the MTR WTS were considered as Super-Sprint distance races due to its mass start and the lack of Super-Sprint races in the WTS circuit (except those in an eliminatory format). Data from 2,411 female and 2,640 male elite triathletes (n = 5051) were examined. Triathletes who dropped out or were disqualified were not included in the analysis (n = 184). All the data used in the study were publicly accessible through the World Triathlon database (Triathlon, 2024), thus informed consent was not required.

Measures

The split times (in seconds) for each segment (swimming, cycling, and running) and transition (T1 and T2), as well as the final positions, were obtained from the race results of each event.

To obtain homogeneous data, not only by distance (Super-Sprint, Sprint, and Olympic) and sex but also by championship and venue, given the climatic and orographic differences (Zhao et al., 2024), a normalised 0–100 score was calculated for each triathlete. Each independent variable was normalized within each sex, competition, and venue. Specifically, for a given race, the best-performing athlete received a value of 0, while the worst-performing athlete received a value of 100. The normalization was performed using the following formula:

$$\frac{SplitTime_{triathlete} - FastestSplitTime_{venue\_year\_sex}}{SlowestSplitTime_{venue\_year\_sex} - FastestSplitTime_{venue\_year\_sex}} * 100$$

This approach ensured that performance was assessed relative to the fastest and slowest split times within each specific race category. Lower values, closer to zero, indicated better performances in that segment or transition.

Statistical Analysis

Model assumptions of normality and homoscedasticity were assessed using the Kolmogorov-Smirnov test and residuals graphics, respectively. Triathletes whose split times exceeded two standard deviations from the mean in each competition (grouped by venue and sex) were excluded (Nkechinyere et al., 2015). The final analysis included 2,113 male and 2,004 female athletes across Super-Sprint (9 male races, 130 athletes; 10 female races, 159 athletes), Sprint (18 male races, 796 athletes; 18 female races, 766 athletes), and Olympic distances (29 male races, 1,227 athletes; 29 female races, 1,039 athletes).

A general linear model (GLM) was used to examine the association between the explanatory variables (normalised scores of the swim, T1, cycle, T2 and run) and the target variable (final position). For each distance and sex, specific models were developed, also, the R2 coefficient was calculated. The beta coefficients (β) showed the degree of change in the outcome (target) variable for every 1 unit of change in the predictor (explanatory) variable. A p-value < 0.05 in the linear regression model was considered significant.

Additionally, decision tree models for the Top-10 triathletes were used to assess the impact of each segment and transition on overall performance for each distance and sex. Following this approach, the normalised scores of each competition for each discipline (swimming, cycling and running), transition (T1 and T2) and gender (male or female) were assigned to a group depending on their final position: 1st to 3rd (medallists), 4th to 6th, and 7th to 10th. Six decision trees were generated, and the confusion matrix, based on the validation sample, was computed along with the precision coefficient. Statistical analyses were conducted using R software (version 4.1.2 for Windows).

Results

Split times and the relative contribution of each segment to overall race time, stratified by sex and race distance, are presented in Table 1.

Table 2 shows the results for the final position in men based on the explanatory variables. The three models were statistically significant, with R^2 values of 0.25, 0.42, and 0.80 for the Super-Sprint, Sprint, and Olympic distances, respectively. These values suggest a strong model fit for Olympic distance, but weaker fits for the shorter races. In males, swimming performance scores were negatively associated with final positions in both the Super-Sprint and Sprint distances (β = −0.05 and −0.06, respectively), whereas a positive association was observed in the

Olympic distance (β = 0.08). Similarly, cycling performance showed positive associations in both the Sprint and Olympic distances (β = 0.03 and 0.18, respectively). Notably, running performance had the strongest associations across all three distances, with β values of 0.13, 0.27, and 0.39 for the Super-Sprint, Sprint, and Olympic distances, respectively. Additionally, transitions were found to be associated with final positions, with both T1 and T2 playing significant roles in the Sprint (β = 0.08 and 0.05, respectively) and Super-Sprint distances (β = 0.02 and 0.03, respectively). In the Olympic distance, only T1 was positively associated with the final result, whereas T2 performance was negatively associated with a better result (Table 2).

Table 3 presents the results for the final position for females based on the performance across different segments. Consistently with the results for men, the models for women were statistically significant, with R^2 values of 0.14, 0.26, and 0.43 for the Super-Sprint, Sprint, and Olympic distances, respectively. These values suggest a moderate model fit, with a higher proportion of variance explained in longer race distances. Female performance in the running segment showed a strong association with final positions across the Super-Sprint, Sprint, and Olympic distances (β = 0.07, 0.11, and 0.23, respectively). Likewise, cycling performance was important for the final result in both the Sprint (β = 0.07) and Olympic distances (β = 0.10). Furthermore, better performance in T1 was associated with improved final positions in the Super-Sprint (β = 0.07) and Sprint distances (β = 0.13), while T2 was particularly relevant for the Sprint and Olympic distances (β = 0.05 and 0.02, respectively).

The decision tree models achieved accuracy exceeding 54.55%, with some reaching up to 71.44%, demonstrating strong predictive capability. The models further indicated that running was the most important segment (%) for the Top-10 across all three distances, for both males and females in terms of model error reduction and predictive capacity (Table 4).

The decision trees suggest that male triathletes who achieve running performances within the top 3.1% for the Sprint distance and top 5.1% for the Olympic distance (based on normalised scores) have a high probability of winning medals. In the Olympic distance, if running performance is not as strong (within the top 17%), athletes must compensate with an outstanding cycling performance, placing them in the top 5.7% for cycling and the top 36% for swimming. In contrast, for the Super-Sprint distance, athletes need a running split within the top 1.8% and a T2 transition time within the top 20% of all competitors (Figure 1).

For female triathletes, achieving running time splits within 0.85% and 5.1% in Super-Sprint and Sprint distance races, respectively, significantly increases the chances of winning medals. However, if running split times exceed 0.85% in the Super-Sprint distance, a swimming segment within the top 0.51% must be performed to secure a medallist position. In contrast, to achieve a medallist position in the Olympic distance, running splits within the top 5.1% of the fastest running splits must be accomplished after completing the cycling and T1 segments within the top 19%. If the running split exceeds 5.6% of the best running split, a swimming segment within the top 18% and a cycling split below 2.6% are required to have any possibility of medalling (Figure 2).

Discussion

The main findings of the present study indicate that the importance of the different triathlon segments varies based on the race distance, sex, and the performance level. Performance in the running segment demonstrated the greatest importance in the final outcome across all distances and both sexes. However, the cycling segment had a greater impact on the final performance as the race distance increased, while swimming showed a little relationship with the final result. On the other hand, transitions, particularly T1, were shown to significantly influence the final position in certain distances, depending on sex and the performance level. These results largely confirm our hypothesis, as running performance emerged as the strongest predictor of the overall outcome across all distances and both sexes; additionally, the increased influence of transition phases in shorter races, particularly among female athletes, was also observed, supporting our secondary hypothesis.

Table 1. Split times and segment contribution (%) to overall race time (mean ± SD) by sex and distance in World Triathlon Series Events (2017–2024).

		Male		Female	
		Split time	%	Split time	%
Super-Sprint	Swim	03:43 ± 00:11	18.22 ± 0.92	03:56 ± 00:13	18.17 ± 0.99
	T1	00:52 ± 00:21	4.27 ± 1.72	00:48 ± 00:12	3.73 ± 0.89
	Bike	10:03 ± 00:40	49.36 ± 3.24	10:48 ± 00:48	49.90 ± 3.66
	T2	00:25 ± 00:04	2.02 ± 0.36	00:27 ± 00:04	2.04 ± 0.33
	Run	05:19 ± 00:30	26.13 ± 2.43	05:40 ± 00:34	26.16 ± 2.63
Sprint	Swim	09:02 ± 00:18	16.47 ± 0.54	09:41 ± 00:20	16.06 ± 0.56
	T1	00:54 ± 00:19	1.66 ± 0.58	01:00 ± 00:22	1.65 ± 0.60
	Bike	28:56 ± 01:44	52.81 ± 3.17	31:35 ± 01:54	52.37 ± 3.14
	T2	00:26 ± 00:05	0.78 ± 0.16	00:28 ± 00:06	0.77 ± 0.15
	Run	15:30 ± 00:48	28.28 ± 1.45	17:35 ± 00:52	29.15 ± 1.43
Olympic	Swim	18:03 ± 01:43	16.85 ± 1.60	19:12 ± 01:58	16.33 ± 1.67
	T1	00:55 ± 00:15	0.86 ± 0.23	01:01 ± 00:17	0.87 ± 0.24
	Bike	55:59 ± 05:41	52.25 ± 5.30	1:01:20 ± 06:38	52.14 ± 5.63
	T2	00:25 ± 00:05	0.39 ± 0.07	00:27 ± 00:04	0.39 ± 0.06
	Run	31:45 ± 03:13	29.64 ± 3.00	35:37 ± 03:51	30.28 ± 3.28

Table 2. General linear model for predicting males' final positions as a function of normalized scores (Nor) for the swim, T1, cycle, T2, and run segments in Super-Sprint, Sprint, and Olympic distance races of the World Triathlon Series from 2017 to 2024.

Males	Estimate (β)	Std. Error	t-statistic	*p*-value	R^2	F-statistic *p*-value
			Super-Sprint			
(Intercept)	6.98	1.23	5.66	< 0.001***	0.25	0.001
Nor_Swim	−0.05	0.01	−2.53	0.01*		
Nor_Bike	−0.08	0.04	−1.82	0.07		
Nor_Run	0.14	0.03	3.84	< 0.001***		
Nor_T1	0.02	0.02	0.99	0.32		
Nor_T2	0.03	0.02	1.38	0.17		
			Sprint			
(Intercept)	8.13	1.17	6.95	< 0.001***	0.42	< 0.001
Nor_Swim	−0.06	0.01	−4.49	< 0.001***		
Nor_Bike	0.04	0.01	2.51	0.01*		
Nor_Run	0.28	0.01	15.42	< 0.001***		
Nor_T1	0.08	0.01	5.22	< 0.001***		
Nor_T2	0.05	0.01	3.18	< 0.01**		
			Olympic			
(Intercept)	−0.73	0.49	−1.46	0.14	0.80	< 0.001
Nor_Swim	0.09	0.00	13.19	< 0.001***		
Nor_Bike	0.18	0.06	27.39	< 0.001***		
Nor_Run	0.39	0.007	52.42	< 0.001***		
Nor_T1	0.03	0.007	3.97	< 0.001***		
Nor_T2	−0.02	0.007	−3.14	< 0.01**		

*Note. A positive β value indicates that an increase of one unit in the segment (i.e., a slower performance in the normalized score) corresponds with a decline in the final ranking. Conversely, a negative β suggests that as the score in this segment increases, the final ranking improves. Significance codes: * p < 0.05; ** p < 0.01, *** p < 0.001*

Table 3. General linear model for predicting females' final positions as a function of normalized scores (Nor) for the swim, T1, cycle, T2, and run segments in Super-Sprint, Sprint, and Olympic distance races of the World Triathlon Series from 2017 to 2024.

Female	Estimate (β)	Std. Error	t-statistic	*p*-value	R^2	F-statistic *p*-value
			Super-Sprint			
(Intercept)	6.67	0.84	7.93	< 0.001***	0.14	< 0.001
Nor_Swim	−0.01	0.02	−0.67	0.50		
Nor_Bike	-0.01	0.03	−0.48	0.62		
Nor_Run	0.06	0.03	2.04	0.04*		
Nor_T1	0.06	0.01	4.32	< 0.001***		
Nor_T2	0.00	0.02	0.19	0.84		
			Sprint			
(Intercept)	3.79	1.49	2.54	0.01*	0.26	< 0.001
Nor_Swim	0.02	0.02	1.30	0.19		
Nor_Bike	0.07	0.02	3.55	< 0.001***		
Nor_Run	0.11	0.02	5.18	< 0.001***		
Nor_T1	0.13	0.02	7.07	< 0.001***		
Nor_T2	0.05	0.02	2.94	< 0.01**		
			Olympic			
(Intercept)	3.78	0.79	4.76	< 0.001***	0.43	< 0.001
Nor_Swim	0.00	0.01	0.01	0.98		
Nor_Bike	0.10	0.01	9.30	< 0.001***		
Nor_Run	0.23	0.01	18.18	< 0.001***		
Nor_T1	0.00	0.01	0.65	0.51		
Nor_T2	0.02	0.01	2.02	0.04*		

*Note. A positive β value indicates that an increase of one unit in the segment (i.e., a slower performance in the normalized score) corresponds with a decline in the final ranking. Conversely, a negative β suggests that as the score in this segment increases, the final ranking improves. Significance codes: * p < 0.05; ** p < 0.01, *** p < 0.001*

Table 4. Decision tree classification of segment predictive capacity (%) for Top-10 finishes in Super-Sprint, Sprint, and Olympic distance events in the World Triathlon Series from 2017 to 2024.

		Nor_Swim	Nor_T1	Nor_Bike	Nor_T2	Nor_Run
Male	Super-Sprint	16	15	15	15	39
	Sprint	11	4	12	7	67
	Olympic	12	8	9	4	67
Female	Super-Sprint	31	5	9	6	49
	Sprint	23	1	13	2	60
	Olympic	24	10	21	4	40

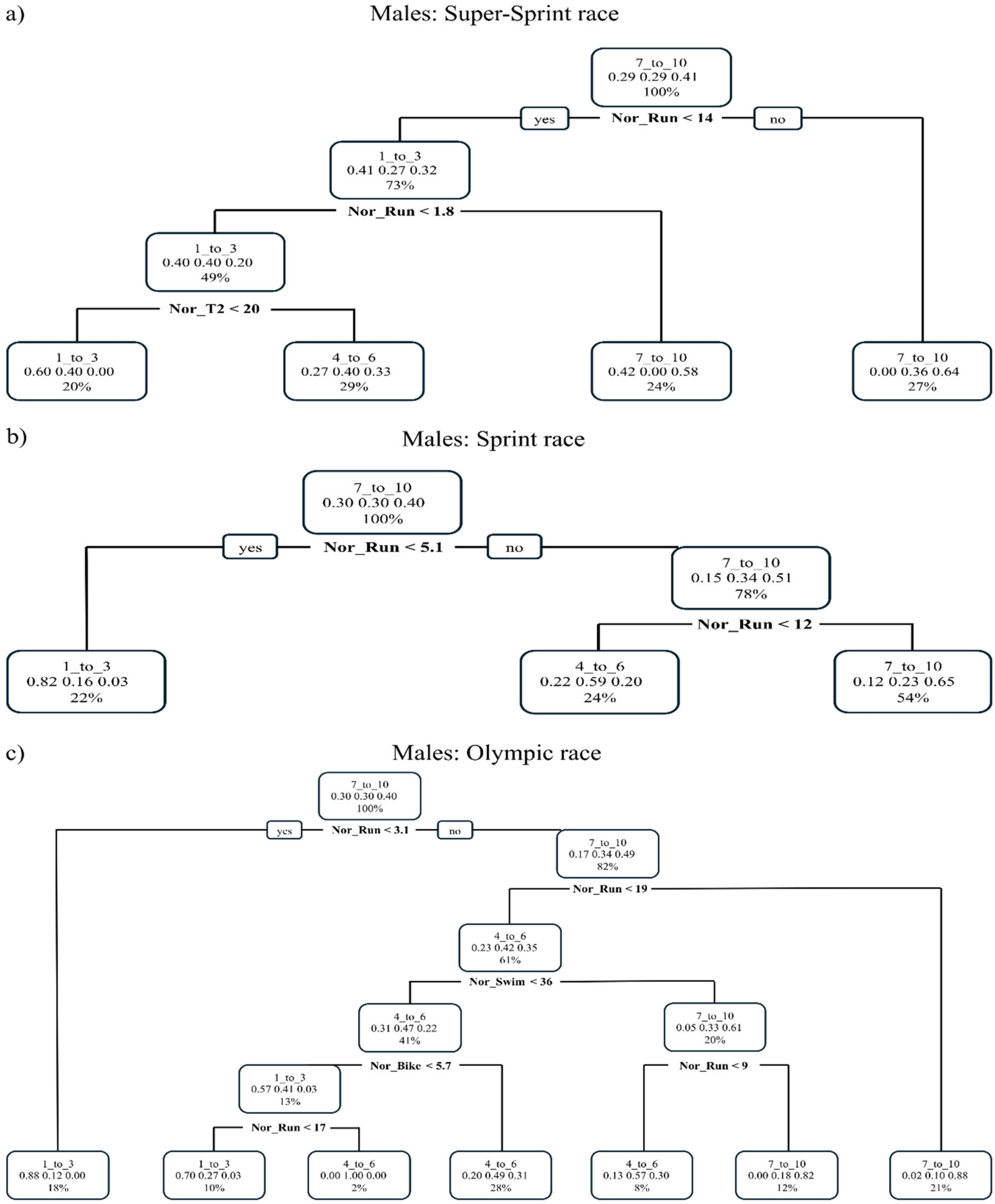

Figure 1. Decision tree classification for normalized split times of the Top-10 male triathletes in the a) Super-Sprint, b) Sprint, and c) Olympic distance races of the World Triathlon Series from 2017 to 2024 (the decision tree categorizes athletes into medallists (1st to 3rd place), those finishing 4th to 6th, and those finishing 7th to 10th).

Note. The terminal leaves of the trees indicate that the classification performed contains three rows: the first row indicates the group assigned by the tree, the second row shows the distribution of individuals in the leaf across the three groups, and the third row represents the proportion of the sample included in that leaf.

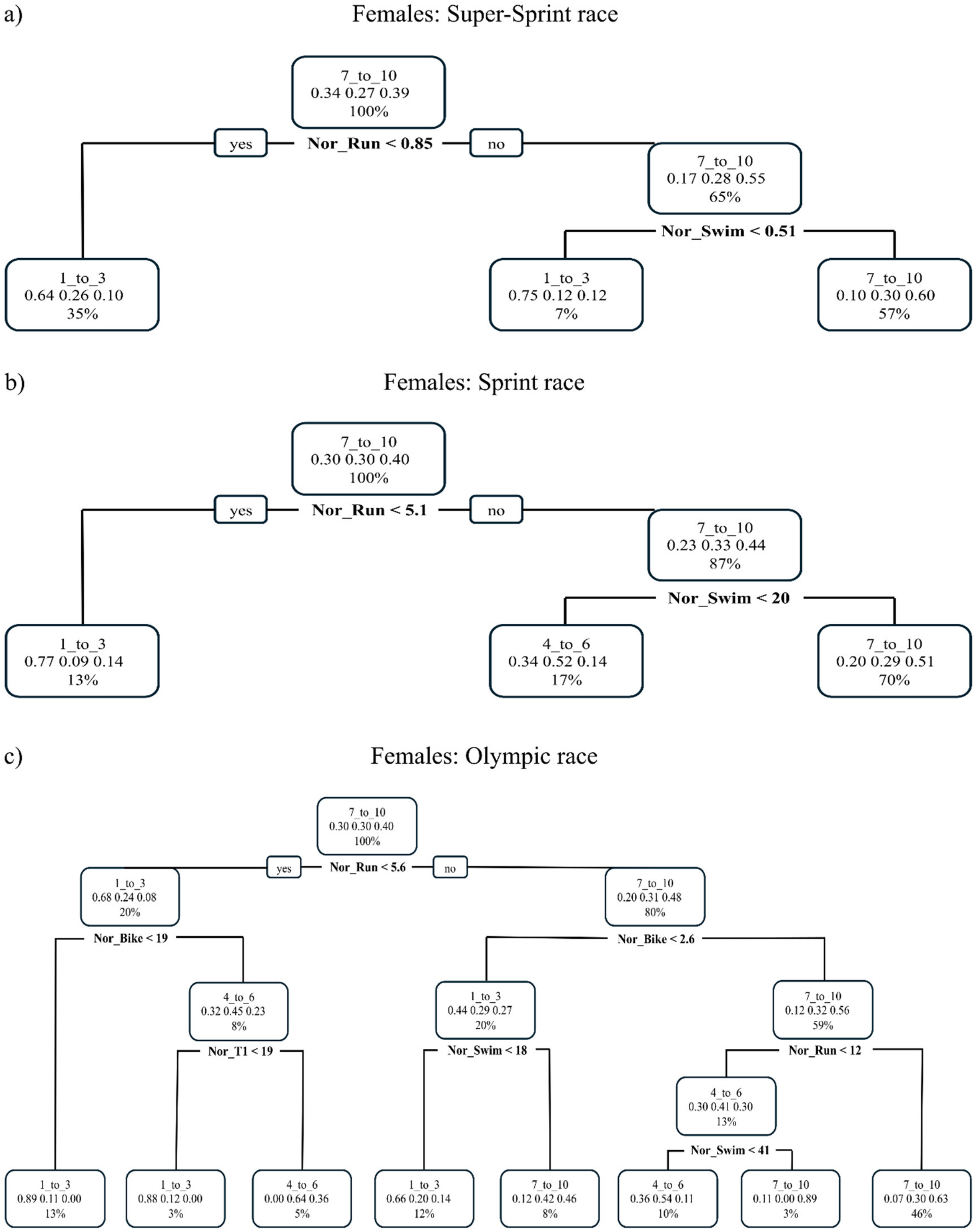

Figure 2. Decision tree classification for normalized split times of the Top-10 female triathletes in the a) Super-Sprint, b) Sprint, and c) Olympic distance races of the World Triathlon Series from 2017 to 2024 (the decision tree categorizes athletes into medallists (1st to 3rd place), those finishing 4th to 6th, and those finishing 7th to 10th).

Note. The terminal leaves of the trees indicate that the classification performed contains three rows: the first row indicates the group assigned by the tree, the second row shows the distribution of individuals in the leaf across the three groups, and the third row represents the proportion of the sample included in that leaf.

In terms of the importance of the different triathlon segments in male races, swimming performance showed a negative association with final results in Super-Sprint and Sprint triathlons, while a positive association was found for the Olympic distance. This finding partially aligns with earlier research in which it was found that swimming was a stronger predictor of performance in Olympic distance triathlons (Sousa et al., 2021). However, in shorter triathlons, the best performers in the swimming segment tended to have lower overall race performance. In addition, we found that the importance of swimming in the Olympic distance was five and two times lower compared to the importance of running and cycling, respectively, in determining the overall position (Table 2). This may be explained by the relatively short time spent on swimming (~17%) compared to cycling and running (~51% and ~28%, respectively) (Table 1), as well as the drafting effect, which may help reduce the performance gap of weaker swimmers (Chatard and Wilson, 2003). Likewise, cycling performance exhibited a negative relationship with the final placement in Super-Sprint races ($\beta = -0.08$), but demonstrated a greater influence on the final outcome in Sprint and Olympic distance triathlons ($\beta = 0.04$ and 0.18, respectively). This negative relationship observed in Super-Sprint races may be partly explained by the shorter race duration, which limits the potential time gains achievable in the cycling segment compared to longer distances. Additionally, the higher relative intensity of the shorter cycling leg, combined with a reduced influence of drafting due to smaller participant groups in our sample, might have impaired subsequent running performance and reduce the overall benefit of strong cycling splits; however, this interpretation is speculative, and further research is needed to confirm these potential mechanisms. Overall, our findings suggest that cycling was seven times less relevant than running in determining the overall result in Sprint distance triathlons ($\beta = 0.04$ vs. 0.28, respectively). This contradicts an earlier study on male elite triathletes, which identified cycling as the most critical factor for the final placement in Sprint distance triathlons (Olaya et al., 2021). However, the differences in results between these studies may be attributed to variations in the competition metrics analysed, such as the time relative to the winner, and in the statistical methods used, such as correlation analyses that may not fully account for the relative importance of each segment in the overall result. In contrast to swimming and cycling, running performance was found to be the most important segment across all distances, with its significance increasing as the distance grew (β = 0.13, 0.27 and 0.39 for Super-Sprint, Sprint and Olympic distance, respectively), showing up to two to nine times more influence than swimming or cycling (Table 2). This may be explained by the fact that as running distance increases, the time differences between athletes tend to grow, especially since running is less affected by the benefits of drafting (Trenchard et al., 2017) compared to swimming (Chatard and Wilson, 2003) and cycling (Hausswirth et al., 1999). These findings align with previous studies which have identified running as the most decisive discipline in Super-Sprint (Espejo et al., 2024), Mixed-Team-Relays (Martínez-Sobrino et al., 2023, 2024) and Olympic distance triathlons (Ofoghi et al., 2016; Piacentini et al., 2019), though no study has provided a specific quantitative measure of this importance. Interestingly, unlike other studies (Cejuela et al., 2012; Olaya et al., 2021), transition performance played a significant role in the overall outcome, especially in Sprint distance triathlons, where T1 and T2 demonstrated greater relevance ($\beta = 0.08$ and 0.05, respectively) compared to cycling ($\beta = 0.03$). T1 performance also was found to influence Olympic distance results, although its impact was smaller compared to swimming, cycling, and running. In contrast, T2 showed a negative relationship with the overall Olympic distance result ($\beta = -0.02$). This negative association may be explained by the fact that a strong T2 performance can place an athlete at the front of a large group at the start of the run segment, potentially encouraging an overly aggressive early pace. Etxebarria et al. (2021) reported that an even pacing strategy during the run segment of Olympic-distance events was associated with better overall performance than a positive pacing strategy, which may help explain this outcome. However, these findings are noteworthy, as transitions account for a small proportion of the total race time, and previous analyses have shown they have limited impact on overall results (Olaya et al., 2021), aside from qualitative or tactical considerations (Piacentini et al., 2019). Only Ofoghi et al. (2016) reported a 1.3-s average difference in T1 between medallists and those finishing outside the Top-10 in Olympic distance events.

For the Top-10 elite male positions, running consistently emerged as the segment with the highest predictive capacity across all distances (Table 4). Previous research has shown that in Super-Sprint (Espejo et al., 2024), Olympic distance (Vleck et al., 2008) and Mixed-Team-Relays (Martínez-Sobrino et al., 2024), athletes in leading positions often begin the running segment together. As a result, their performance during the running segment is the key factor in determining the final rankings. To be a medallist, triathletes should aim to achieve normalised split times within the top 5.1% for the running segment of Sprint distance events and the top 3.1% for Olympic distance events (Figure 1). In the same line, Ofoghi et al. (2016) reported that 51% of medallists in Olympic distance triathlons completed the running split within 10 s of the fastest split. On the other hand, swimming and cycling contributed more substantially to the reduction of model error when predicting Top-10 outcomes in Super-Sprint events compared to Sprint and Olympic distances (Table 4). While running remains the most important segment, being part of the lead pack during the swimming and cycling segments is crucial for medal-winning triathletes in Super-Sprint distance triathlons, who consistently occupy top-8 positions (Espejo et al., 2024). Notably, transition performance contributed approximately 30% to the reduction in model error in the Top-10 Super-Sprint finishers, a proportion comparable to that of swimming and cycling, and nearly three times greater than in Sprint and Olympic distances (11% and 12%, respectively). This suggests that, in shorter competitions, small time differences achieved during transitions are more informative for distinguishing between high-performing athletes. In fact, among Super-Sprint athletes who achieved running times within the top 1.8%, T2 performance became a decisive factor in distinguishing medallists (top 20% times) from those finishing 4th to 6th (Figure 1a). Completing a fast T2 and widening the time gap relative to other competitors in the same pack may trigger a psychophysiological response, such as the sensation of 'falling behind' or 'pulling away' depending on the accumulated distance from the leader (Venhorst et al., 2018), that could partially explain these observed patterns.

In female races, in line with results in male competitions, cycling and running performances became more significant as race distance increased, with cycling playing a notable role in Sprint and Olympic distances (β = 0.07 and 0.10, respectively). Given that female triathletes may face greater challenges in bridging the gaps with competitors (Vleck et al., 2008), cycling performance appears to be especially important for success across all triathlon distances (Espejo et al., 2024; Olaya et al., 2021; Piacentini et al., 2019). However, running consistently carries the greatest weight across all distances compared to swimming and cycling, contributing twice as much to the overall results as cycling in both Sprint (β = 0.13 vs. 0.07) and Olympic distance events (β = 0.23 vs. 0.10). Since running is minimally influenced by drafting (Trenchard et al., 2017), female triathletes compete under similar conditions in this segment, making individual weaknesses more impactful and potentially leading to poorer final results (Piacentini et al., 2019). Remarkably, transitions play a crucial role in the overall result, with T1 being as important as running performance in Super-Sprint distances (β = 0.07 for both) and the most significant segment in Sprint distances, surpassing running (β = 0.13 vs 0.11). Vleck et al. (2008) emphasized that a fast T1 is crucial for joining the lead cycling pack, as the time gaps between the lead and second female packs widened by the end of the first bike lap and remained steady as both packs advanced. Furthermore, T2 performance has also been found to be significant for Sprint and Olympic distance races, although its influence on the overall result is the lowest. It is important to note that T1 is usually longer than T2 (Cejuela et al., 2012) and often involves long running distances and wetsuit removal, which may also explain its greater significance. Unlike the other segments, swimming has been found to have no impact on the overall female results at any distance. This may be because swimming is the shortest segment of the triathlon and occurs furthest from the finish line, with drafting minimising individual weaknesses.

For the Top-10 women positions, running performance contributed the most to the reduction of model error, ranging from 40% to 60%, followed by swimming (23% to 31%) and cycling (9% to 21%) (Table 4). As females are less able to bridge the gaps in the cycling segment (Vleck et al., 2008), to be in the first swimming pack and to run the best time splits may be key distinguishing factors for positioning within the Top-10 (Landers et al., 2008; Piacentini et al., 2019). However, transitions contributed less to the model's predictive performance for Top-10 female triathletes across all distances. As previously reported in female triathlon competitions (Espejo et al., 2024; Vleck et al., 2008), packs of about 10 to 20 triathletes after the swim and during the cycling segment may lessen the relative importance of transitions and enhance the role of swimming and running performances in differentiating between higher-ranked athletes. To contend for medals, females should run within the top 0.85% for Super-Sprint or 5.1% for Sprint distance competitions. Otherwise, triathletes should swim within the top 0.51% to get a medal in Super-Sprint triathlons. These results underscore the importance of achieving the fastest running splits to secure a medal, as previously observed in young Super-Sprint triathletes (Espejo et al., 2024). This is likely due to reduced drafting benefits, requiring athletes to excel individually or gain a time gap in swimming to offset losses in the running segment; however, this interpretation should be considered cautiously, and further research is needed to confirm these observations. In Olympic distance events, female triathletes need to perform exceptionally well in running (top 5.6%) and either cycling or T1 (top 19% for both) to secure a medal. If they are not exceptional runners (below 5.6%), they need to perform well in swimming (top 18%) and have an outstanding cycling segment (top 2.6%) to achieve a medal. While running remains the most decisive factor for winning medals in the Olympic distance (Gadelha et al., 2020), these results suggest that athletes with weaker running performances can still contend for medals by capitalizing on breakaways in the earlier segments.

However, some limitations should be considered when interpreting the present results. Since there are no mass-start Super-Sprint competitions without elimination in the WTS circuit, data were collected from the first leg of MTR events. As a result, the sample sizes per competition were smaller compared to other race distances. Additionally, technological and regulatory changes over the years may have introduced slight performance variations not captured in this analysis.

Conclusions

The most important segment for triathlon performance, regardless of distance (Super-Sprint, Sprint and Olympic), is the running segment, as it consistently plays a decisive role in determining final outcomes for both men and women. There is a trend for the cycling and running segments to gain greater importance as the competition distance increases, while swimming generally has minimal impact on final results, at least in homogenous groups of triathletes with well-developed swimming skills such as the competitor in the WTS. However, for Top-10 female finishers, swimming performance plays a more substantial role. This highlights the importance of women staying close to the leader after the swimming segment. The analysis also reveals a remarkable role of transitions, especially in shorter distances for overall results, where improving transition performance can have a greater impact on final results than swimming or cycling. Additionally, female triathletes, unlike their male counterparts, place greater importance on transitions for overall results, with T1 playing a particularly significant role in determining outcomes in Sprint and Super-Sprint races. This information is highly valuable for coaches in designing tailored training plans and competition strategies.

Author Contributions: Conceptualization: J.M.-S. and S.V.; methodology: J.M.-S. and S.V.; software: J.S.d.C.; formal analysis: J.S.d.C. and J.M.G.-R.; investigation: J.M.-S.; data curation: J.M.-S. and J.S.d.C.; writing—original draft preparation: J.M.-S. and S.V.; writing—review & editing: J.S.d.C., J.M.G.-R. and S.V.; visualization: J.M.-S. and J.S.d.C; supervision: S.V. and J.M.G.-R.; project administration: S.V. and J.M.G.-R. All authors have read and agreed to the published version of the manuscript.

ORCID iD:

Jesús Martínez-Sobrino: https://orcid.org/0000-0003-0657-3187

Jesús Santos del Cerro: https://orcid.org/0000-0002-1384-6334

José María González-Ravé: https://orcid.org/0000-0001-5953-4742

Santiago Veiga: https://orcid.org/0000-0002-4183-3231

Funding Information: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent: Not applicable.

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

Received: 01 September 2025

Accepted: 10 April 2026

References

Barbosa, L. P., Sousa, C. V., Sales, M. M., Olher, R. D. R., Aguiar, S. S., Santos, P. A., Tiozzo, E., Simões, H. G., Nikolaidis, P. T., & Knechtle, B. (2019). Celebrating 40 Years of Ironman: How the Champions Perform. *International Journal of Environmental Research and Public Health*, *16*(6), 1019. https://doi.org/10.3390/ijerph16061019

Cejuela, R., Cala, A., Perez-Turpin, J. A., Villa, J. G., Cortell, J. M., & Chinchilla, J. J. (2013). Temporal Activity in Particular Segments and Transitions in The Olympic Triathlon. *Journal of Human Kinetics, 36*, 87–95. https://doi.org/10.2478/hukin-2013-0009

Cejuela, R., Cortell-Tormo, J. M., Chinchilla-Mira, J. J., Perez-Turpin, J. A., & Villa, J. G. (2012). Gender differences in elite Olympic distance triathlon performances. *Journal of Human Sport and Exercise*, *7*(2), 434–445. https://doi.org/10.4100/jhse.2012.72.09

Chatard, J.-C., & Wilson, B. D. (2003). Drafting distance in swimming. *Medicine and Science in Sports and Exercise, 35*(7), 1176–1181.

Espejo, R., Martinez-Sobrino, J., & Veiga, S. (2024). Race strategies of young super-sprint triathletes during the 2022 World Triathlon races. *International Journal of Performance Analysis in Sport, 24*(6), 587–600. https://doi.org/10.1080/24748668.2024.2337529

Etxebarria, N., Wright, J., Jeacocke, H., Mesquida, C., & Pyne, D. B. (2021). Running Your Best Triathlon Race. *International Journal of Sports Physiology and Performance*, *16*(5), 744–747. https://doi.org/10.1123/ijspp.2020-0838

Gadelha, A. B., Sousa, C. V., Sales, M. M., dos Santos Rosa, T., Flothmann, M., Barbosa, L. P., da Silva Aguiar, S., Olher, R. R., Villiger, E., Nikolaidis, P. T., Rosemann, T., Hill, L., & Knechtle, B. (2020). Cut-Off Values in the Prediction of Success in Olympic Distance Triathlon. *International Journal of Environmental Research and Public Health, 17*(24), 9491. https://doi.org/10.3390/ijerph17249491

Hausswirth, C., Lehénaff, D., Dréano, P., & Savonen, K. (1999). Effects of cycling alone or in a sheltered position on subsequent running performance during a triathlon. *Medicine & Science in Sports & Exercise, 31*(4), 599–604. https://doi.org/10.1097/00005768-199904000-00018

Landers, G. J., Blanksby, B. A., Ackland, T. R., & Monson, R. (2008). Swim Positioning and its Influence on Triathlon Outcome. *International Journal of Exercise Science, 1*(3), 96–105. https://doi.org/10.70252/KRDW4369

Martínez-Sobrino, J., Del Cerro, J. S., González-Ravé, J. M., & Veiga, S. (2024). Race Dynamics in Triathlon Mixed-Team-Relay Meaningfully Changes with The New Regulation Towards Paris 2024. *Journal of Sports Science and Medicine, 23*(2), 358–365. https://doi.org/10.52082/jssm.2024.358

Martínez-Sobrino, J., Veiga, S., Santos del Cerro, J., & González-Ravé, J. M. (2023). What is the Most Important Leg and Discipline in Triathlon Mixed Team Relays?. *Journal of Human Kinetics, 89*, 269–278. https://doi.org/10.5114/jhk/167088

Nkechinyere, E. M., I, I. A., & Idochi, O. (2015). Comparison of Different Methods of Outlier Detection in Univariate Time Series Data. *International Journal For Research In Mathematics And Statistics, 1*(1), 55–83. https://doi.org/10.53555/ms.v1i1.912

Ofoghi, B., Zeleznikow, J., Macmahon, C., Rehula, J., & Dwyer, D. B. (2016). Performance analysis and prediction in triathlon. *Journal of Sports Sciences, 34*(7), 607–612. https://doi.org/10.1080/02640414.2015.1065341

Olaya-Cuartero, J., Fernandez-Saez, J., Osterlie, O., & Ferriz-Valero, A. (2022). Concordance Analysis between the Segments and the Overall Performance in Olympic Triathlon in Elite Triathletes. *Biology, 11*(6), 902. https://doi.org/10.3390/biology11060902

Olaya, J., Fernández-Sáez, J., Østerlie, O., & Ferriz-Valero, A. (2021). Contribution of segments to overall result in elite triathletes: Sprint distance. *International Journal of Environmental Research and Public Health, 18*(16), 8422. https://doi.org/10.3390/ijerph18168422

Piacentini, M. F., Bianchini, L. A., Minganti, C., Sias, M., Di Castro, A., & Vleck, V. (2019). Is the Bike Segment of Modern Olympic Triathlon More a Transition towards Running in Males than It Is in Females? *Sports, 7*(4), 76. https://doi.org/10.3390/sports7040076

Quagliarotti, C., Gaiola, D., Bianchini, L., Vleck, V., & Piacentini, M. F. (2022). How to Form a Successful Team for the Novel Olympic Triathlon Discipline: The Mixed-Team-Relay. *Journal of Functional Morphology and Kinesiology, 7*(2), 46. https://www.mdpi.com/2411-5142/7/2/46

Sousa, C. V., Aguiar, S., Olher, R. R., Cunha, R., Nikolaidis, P. T., Villiger, E., Rosemann, T., & Knechtle, B. (2021). What Is the Best Discipline to Predict Overall Triathlon Performance? An Analysis of Sprint, Olympic, Ironman (R) 70.3, and Ironman (R) 140.6. *Frontiers in Physiology, 12*, 654552. https://doi.org/10.3389/fphys.2021.654552

Trenchard, H., Renfree, A., & Peters, D. M. (2017). A Computer Model of Drafting Effects on Collective Behavior in Elite 10,000-m Runners. *International Journal of Sports Physiology and Performance, 12*(3), 345–350. https://doi.org/10.1123/ijspp.2016-0026

Venhorst, A., Micklewright, D., & Noakes, T. D. (2018). Modelling the process of falling behind and its psychophysiological consequences. *British Journal of Sports Medicine, 52*(23), 1523–1528. https://doi.org/10.1136/bjsports-2017-097632

Vleck, V., Bentley, D., Millet, G., & Buergi, A. (2008). Pacing during an elite Olympic distance triathlon: Comparison between male and female competitors. *Journal of Science and Medicine in Sport, 11*(4), 424–432. https://doi.org/10.1016/j.jsams.2007.01.006

World Triathlon. Retrieved on 01 September 2024 from https://triathlon.org/

World Triathlon Competition Rules (2024). https://www.triathlon.org/uploads/docs/World-Triathlon_Competition-Rules_2024_20240219.pdf, accessed on: 01 September 2024.

Zhao, J., Wu, Y., & Zhang, J. (2024). A study of triathletes' race strategies in different competition environments. *Heliyon, 10*(8), e29454. https://doi.org/https://doi.org/10.1016/j.heliyon.2024.e29454