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ORIGINAL ARTICLE

Analysis and Comparison of Female Triathlon Top-Class Performance at Three Main Competitions over 23 Years Considering Race Position

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ABSTRACT
Background. No articles have been found that simultaneously compare top-class female triathlon performance over the years, across different competitions and between race positions. **Objectives.** This study aims to compare performance levels across significant triathlon female events, to compare the performance of medalist female triathletes with non-medalist female triathletes, and to carry out an analysis of the performance trends in female Olympic-distance triathlon across 23 years (from 2000 to 2023). **Methods.** The dataset for this study was obtained from the ITU World Triathlon Series (WTS) website (http://wts.triathlon.org/). Individual discipline times and overall times from 2000 to 2023 were collected for analysis, excluding 2020 due to the COVID-19 outbreak. The performance has been compared a) between competitions, b) between positions (medalists and non-medalists), and c) across the years. **Results.** The best time never corresponds to the European Championship for any discipline and group. A significant relationship exists between the years and performance for all disciplines, considering both medalists and all athletes (p values <0.001). **Conclusion.** Running time is the most differentiating discipline between the medalists and the rest, although it is not the only one. A causal relationship has been proven between the years and the performance improvement in all disciplines, similar for medalists and all participants. Female triathletes perform better at the World Championship than other competitions.

INTRODUCTION

Triathlon combines the sports disciplines of swimming, cycling, and running in one single event (1). It is formed by two transition phases in which the athletes change from swimming to cycling and cycling to running. The International Triathlon Union (ITU) is the organization that organizes world competitions in various combined sports. Among these sports are duathlon and aquathlon, and the most popular of them all is triathlon. ITU organizes the most popular events for the Olympic distance in triathlon, the World, and the European Championships.

The Olympic distance triathlon involves a 1,500-meter swim, a 40,000-meter bike ride, and a 10,000-meter run. The ITU World Championship was previously held as a single event from 1989 to 2009. However, since 2009, the World Triathlon Series (WTS) competition has been introduced based on races culminating in a Grand Final event. This competition awards points based on the importance and distance of each race. In addition to this, other significant competitions include the Olympic Games, which take place every four years, and the annual European Championship. The ITU, among other triathlon-related institutions, collects and publishes data on race results, among nationalities and years of birth, for all the events they organize. Numerous authors have used this resource to search and address highly relevant research questions (2–5).

These quantitative studies are not limited to triathlons. Some authors have focused on specific issues in other sports, such as Mountain Bike cycling (6). Within the multi-sports field, those that have addressed topics related to duathlon or mountain triathlon can be highlighted. As for the former, some studies analyze the decline in the men-to-women ratio over the years (7), the optimal age for peak performance (8), or the effect of sex and performance level on the pacing of different duathlon distances (9). In the latter case, gender performance differences were examined (10), and age-related performance decline was observed in the three primary disciplines (11). Unfortunately, no aquathlon-related studies have been found.

With an exclusive focus on triathlon, it is worth highlighting the review by Lepers et al., (2014) (12), which provides a comprehensive analysis of triathlon performance concerning the sex and age of athletes. However, as previously mentioned, triathlon includes various categories and distances. Some authors have investigated these distances (3, 13, 14) or other categories (15). In the literature, numerous articles have quantitatively analyzed triathlon at longer distances than the Olympic one (16). The gender comparison has been a focal point for many authors (13, 17–20). The peak performance age and the evolution of performance relating to age have also been investigated in several research studies (5, 14, 21–23).

Some investigations conduct longitudinal analyses over years and even decades. Rüst et al., (2012) (20) did so for previously discussed issues such as running performance and sex differences. Others examined performance trends in ultra-triathlons (24–26). The focus on performance is also evident in several other long-distance triathlons. Previous studies aimed to determine the best predictable variable for an Ironman race time in recreational male triathletes (27) or for different ultra-triathlon races (28). Instead, others compared the performance of different races as the Triple Deca Iron with the Deca Iron (29). Other articles have focused on less popular distances, such as the sprint (30) or the super sprint in the mixed-team-relay category (15).

Moving on to the Olympic triathlon, a broad research focus has been explored. Some have adopted a physiological perspective, with specific articles focusing on the details of sex disparities (13). As for the studies that have a quantitative analytical approach to Olympic triathlon, specific authors have aimed to foresee young talents (31). In contrast, some others aimed to assess the impact of the COVID-19 pandemic on the ITU Triathlon, Duathlon, and Aquathlon World Championship (32, 33). Other previously mentioned articles have examined the longitudinal performance evolution concerning age within this distance (2, 23).

The primary focus of the research of other authors has been to find out the impact of each discipline's performance on the final overall performance. The consensus among most authors is that cycling has the least influence while running holds the most significant impact (4, 34, 35). In contrast, some authors argue that swimming is the top predictor of overall performance (3). Only one article attributes the top predictor of the final outcome to the cycling segment (36). This determination is based on concordance analysis, a novel approach that might consider inter-subject variability, suggested by the authors as a gold standard.

To conclude the literature review, it is essential to mention studies that have been exclusively dedicated to examining times in Olympic triathlon races and their evolution, which aligns with the research focus of the present study. Rüst et al., (2013) (37) analyzed 28 races across the Olympic cycle from 2009 to 2012, involving the World Triathlon Series and the Olympic Games. Their findings revealed no significant changes in variables except for increased cycling performance and, logically, in the final race times. Wonerow et al., (2017) (38) extended this analysis by an additional two years, categorizing the results by age groups, and concluded that both women and men improved their performance in most age groups over the years. Similarly, other authors found that the final race times remained relatively unchanged over 10 years in nearly all age groups when categorizing results (39).

A literature gap exists comparing significant competitions such as the Olympic Games, ITU World Championship, and ETU European Championship in top-class female triathlon. Furthermore, no articles have been found that compare the overall results of all participating athletes with those of the medalists. Finally, no articles have been found analyzing the performance of elite female triathletes over a long number of years in the 21st century.

Therefore, this study includes three main goals: firstly, to compare performance levels across significant triathlon female events, including the Olympic Games, ITU World Championship, and ETU European Championship; secondly, to compare the performance of medalist female triathletes with non-medalist female triathletes; and lastly, to carry out an analysis of the performance trends in female Olympic-distance triathlon across 23 years (from 2000 to 2023).

Different performance variations across competitions, differences between medalists and non-medalists, and significant performance improvements over the years are hypothesized.

MATERIALS AND METHODS

Data Sampling. The dataset for this study was obtained from the ITU World Triathlon Series (WTS) website (http://wts.triathlon.org/). Since the data were available online, no informed consent was obtained from the participants. Individual discipline times and overall times from 2000 to 2023 were collected for analysis, excluding 2020 due to the COVID-19 outbreak. The total number of athletes included in this study was 2,958. This includes 594 at the Olympic Games, 1,309 at the World Championship, and 1,055 at the European Championship. Starting in 2009, data collection was limited to the Grand Finals, which aligns closely with the World Championship's significance and the timing within the year, making it a suitable representative of the one-single-event World Championship. As a result of poor weather, the swimming distance was halved to 750 m at the London World Championship in 2013. These swimming times were excluded from this study because of their non-comparable distance from the other swimming times.

The analysis included the minimum number of athletes who completed any of the three competitions (Olympic Games, World Championship, and European Championship). Two groups were established: the top three finishers, and the remaining included athletes in each competition. As shown in Figure 1, due to dropouts, disqualifications, and non-starting athletes, the sample size was reduced to 1,147 women. This total of 204 women competed at the Olympic Games, 460 at the World Championship, and 483 at the European Championship. The mean age of subjects overall was 27.26. The minimum number of finishing athletes was considered regardless of competition when linearly correlating the times and years.

External factors such as course variations, environmental conditions, and circuit layout may be influenced by performance trends, which were not considered in this study. The analysis was based solely on a quantitative approach using the available official race results published by the ITU. While this method ensures objectivity, it does not account for physical or environmental factors that could impact race outcomes.

The analyzed variables were as follows:

- Swimming time (ST): time of the swimming performance.
- First transition phase (T1): the first transition phase performance time.
- Cycling time (CT): time of the cycling performance.
- Second transition phase (T2): the second transition phase performance time.
- Running time (RT): time of the running performance.
- Final time (FT): time of the final performance.

Statistical Analysis. Results are presented as mean ± standard deviation (SD). The reliability of the data was assessed using a 95% confidence interval. One-way ANOVA following the pairwise post hoc (Bonferroni) was employed to compare the times between competitions. Student's t-test for independent samples was used to compare medalists with non-medalists. Simple Linear Regressions were employed to analyze the association between performance in each discipline over the years for medalists and all participants, irrespective of the competition. The statistical analysis was performed using IBM SPSS Statistics Version 19. Significance was determined at $p < 0.05$.

The magnitude of differences (Effect Size) was assessed using partial eta-squared (η^2). The effects were evaluated according to the following: 0.01, small; 0.06, medium; 0.14, large.

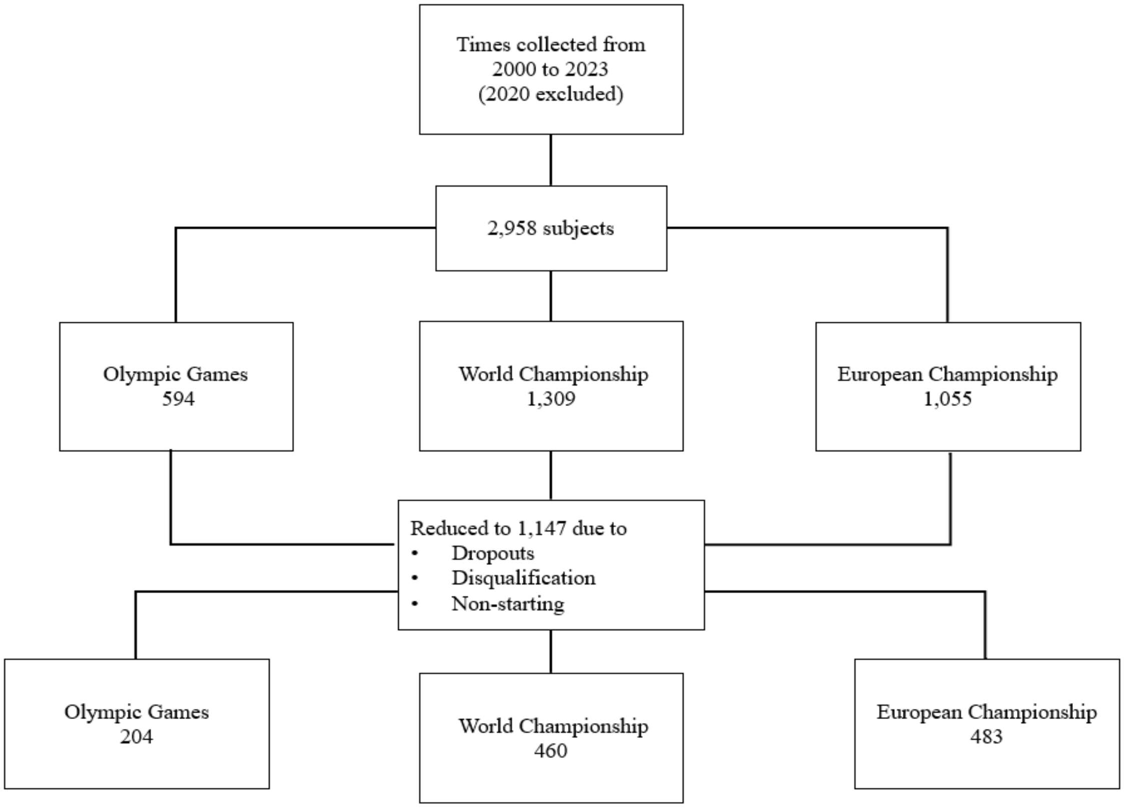

Figure 1. Data collection and sample size.

RESULTS

Comparisons of Performance Between Competitions.

Table 1 shows a significant difference in the time for the First transition phase, with the Olympic Games being significantly lower than the World Championship or European Championship (p values <0.001 / η^2 0.205; 0.152). In the Second transition phase, we observe a significantly longer time (worse performance) than the Olympic Games and the World Championship from the European Championship.

For Cycling, Running, and Final times, the World Championship time is significantly better (lower) than that of the Olympic Games. However, no significant differences were found between the Olympic Games and the World Championship when only medalists were analyzed. In no case does the best time correspond to the European Championship. Post hoc comparisons reveal significant differences between all pairs of competitions in running time and final time for non-medalists, but not when medalists are the only ones (Table 1).

Medalists' Performance vs Non-Medalists' Performance. Figure 2 shows no significant differences in performance in Transition phases between medalists and non-medalists have been found. For the rest of the disciplines, medalists' time has always been lower than non-medalists.

The best time for Swimming time has been significant at the Olympic Games and the World Championship (p values <0.05; <0.01). For Cycling time, this only occurs at the Olympic Games (p-value <0.05). Nonetheless, for Running and Final times, this happens in all three competitions (p values <0.001 for Running time and <0.001; <0.001; <0.01 for Final time at the Olympic Games, World Championship, and European Championship, respectively). Running time always had the most significant effect size in every competition (d 1.417; 0.676; 0.708 for the Olympic Games, World Championship, and European Championship, respectively) (Figure 2).

Table 1. Comparison of times with different competitions (seconds).

		IOC (n=204) Mean ± SD (CI 95%)	ITU (n=460) Mean ± SD (CI 95%)	ETU (n=483) Mean ± SD (CI 95%)	*p*-value	ES (η^2)
Swimming Time	**Non-medalists**	1,177.18 ± 37.60 (1,171.99; 1,182.37)	1160.21 ± 53.03 (1,154.99; 1,165.42)	1165.65 ± 99.40 (1,156.45; 1,174.84)	0.325	0.002
	Medalists	1,156.22 ± 33.35 (1,139.64; 1,172.81)	1,145.53 ± 52.60 (1,131.94; 1,159.12)	1,151.65 ± 96.36 (1,127.38; 1,175.92)	0.840	0.002
First Transition Phase	**Non-medalists**	35.86[a,b] ± 12.27 (34.16; 37.55)	61.58[a] ± 19.77 (59.64; 63.53)	60.26[b] ± 21.69 (58.26; 62.27)	**<0.001**	0.205
	Medalists	35.83[a,b] ± 12.87 (28.43; 41.23)	60.07[a] ± 18.67 (55.24; 64.89)	58.37[b] ± 21.38 (52.98; 63.75)	**<0.001**	0.152
Cycling Time	**Non-medalists**	3,949.07[a] ± 155.78 (3,927.57; 3,970.58)	3,807.60[a,b] ± 274.57 (3,780.58; 3,834.62)	3,968.17[b] ± 353.43 (3,935.46; 4,000.87)	**<0.001**	0.061
	Medalists	3,881.00 ± 141.22 (3,810.77; 3,951.23)	3,776.67[a] ± 271.27 (3,706.59; 3,846.74)	3,919.06[a] ± 341.50 (3,833.06; 4,005.07)	**0.009**	0.060
Second Transition Phase	**Non-medalists**	30.53[a] ± 6.47 (29.64; 31.43)	29.38[b] ± 5.71 (28.82; 29.94)	33.25[a,b] ± 11.14 (32.22; 34.28)	**<0.001**	0.041
	Medalists	29.50 ± 6.20 (26.41; 31.43)	28.57 ± 5.25 (27.21; 29.92)	31.48 ± 9.92 (29.98; 33.37)	0.117	0.031
Running Time	**Non-medalists**	2,198.27[a,b] ± 103.23 (2,184.02; 2,212.52)	2,150.56[a,c] ± 114.10 (2,139.33; 2,161.79)	2,234.17[b,c] ± 119.11 (2,220.83; 2,247.51)	**<0.001**	0.067
	Medalists	2,074.39[a] ± 65.04 (2,042.04; 2,106.73)	2,081.78[b] ± 78.40 (2,061.53; 2,102.04)	2,153.54[a,b] ± 78.40 (2,123.54; 2,183.54)	**<0.001**	0.088
Final Time	**Non-medalists**	7,395.87[a,b] ± 215.21 (7,366,16; 7,425.58)	7,208.28[a,c] ± 319.90 (7,176.80; 7,239.77)	7,461.72[b,c] ± 489.30 (7,416.44; 7,507.00)	**<0.001**	0.079
	Medalists	7,180.56 ± 175.42 (7,093.32; 7,267.79)	7,091.37[a] ± 297.80 (7,014.44; 7,168.30)	7,314.10[a] ± 456.75 (7,199.07; 7,429.13)	**0.002**	0.080

One-way ANOVAs for the comparisons between competitions. The same superscript equals post hoc Bonferroni pairwise differences—student's t-test for independent samples for comparisons of medalists with non-medalists. The effects were evaluated according to the following: 0.01: small; 0.06: medium; 0.14: large; IOC: International Olympic Committee; ITU: International Triathlon Union; ETU: European Triathlon Union.

Performance Trends in Olympic-Distance Triathlon Across 23 Years. Figure 3 shows a significant relationship between the years and performance for all disciplines, considering both medalists and athletes. The p-value is lower than 0.001 for both groups (medalists and all athletes) and all variables (Swimming, Cycling, Running, and Final times). Final time consistently exhibits the highest R^2 value in comparison with other variables. The R^2 values are similar for medalists and all participants in all disciplines.

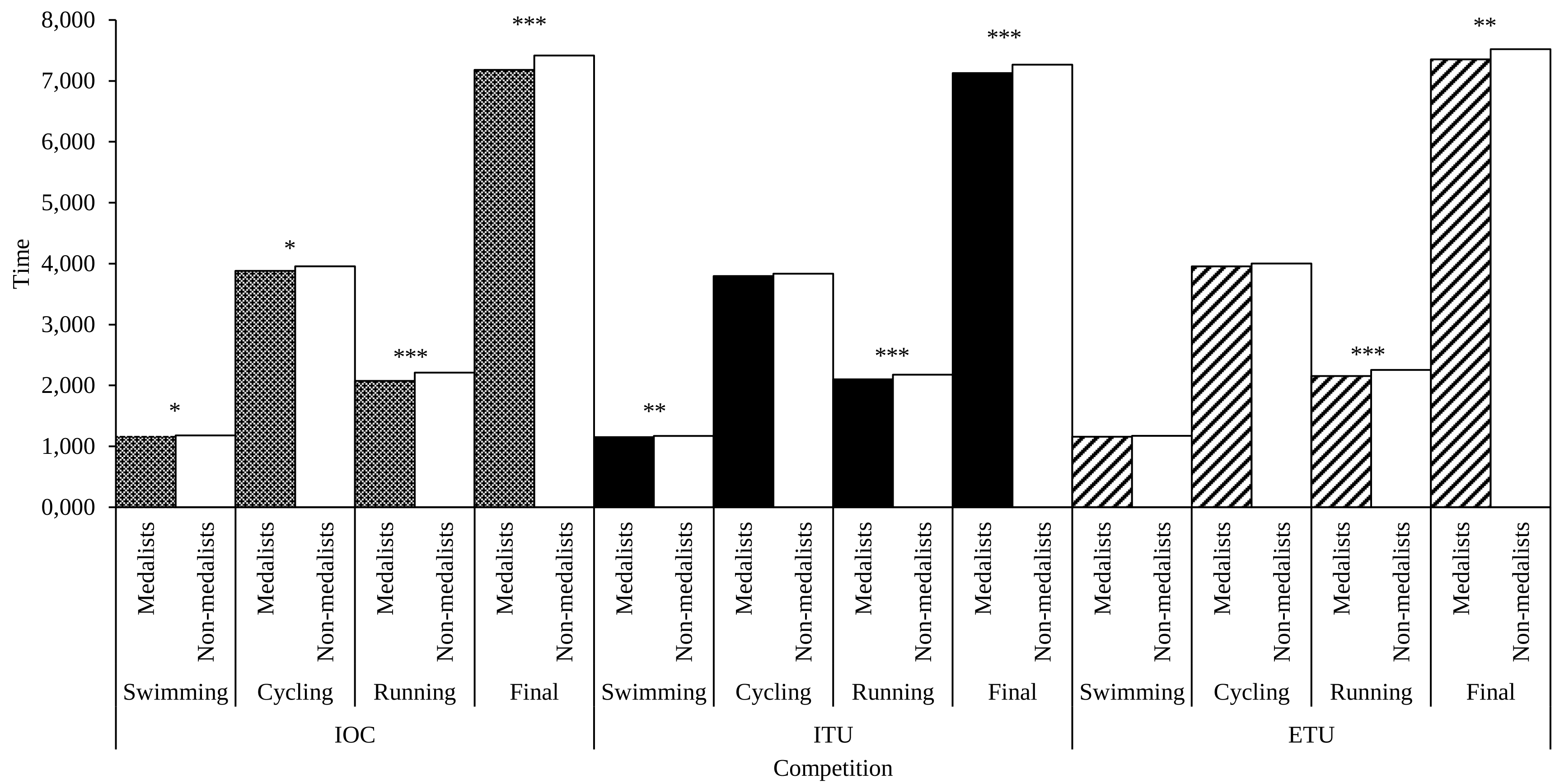

Figure 2. Comparison of medalists and non-medalist times (seconds) in different competitions. Student's t-test for independent samples. Means between medalists and non-medalists are significantly different in at least one discipline (*: p-value <0.05; **: p-value <0.01; ***: p-value <0.001); IOC: Olympic Games; ITU: World Championship; ETU: European Championship.

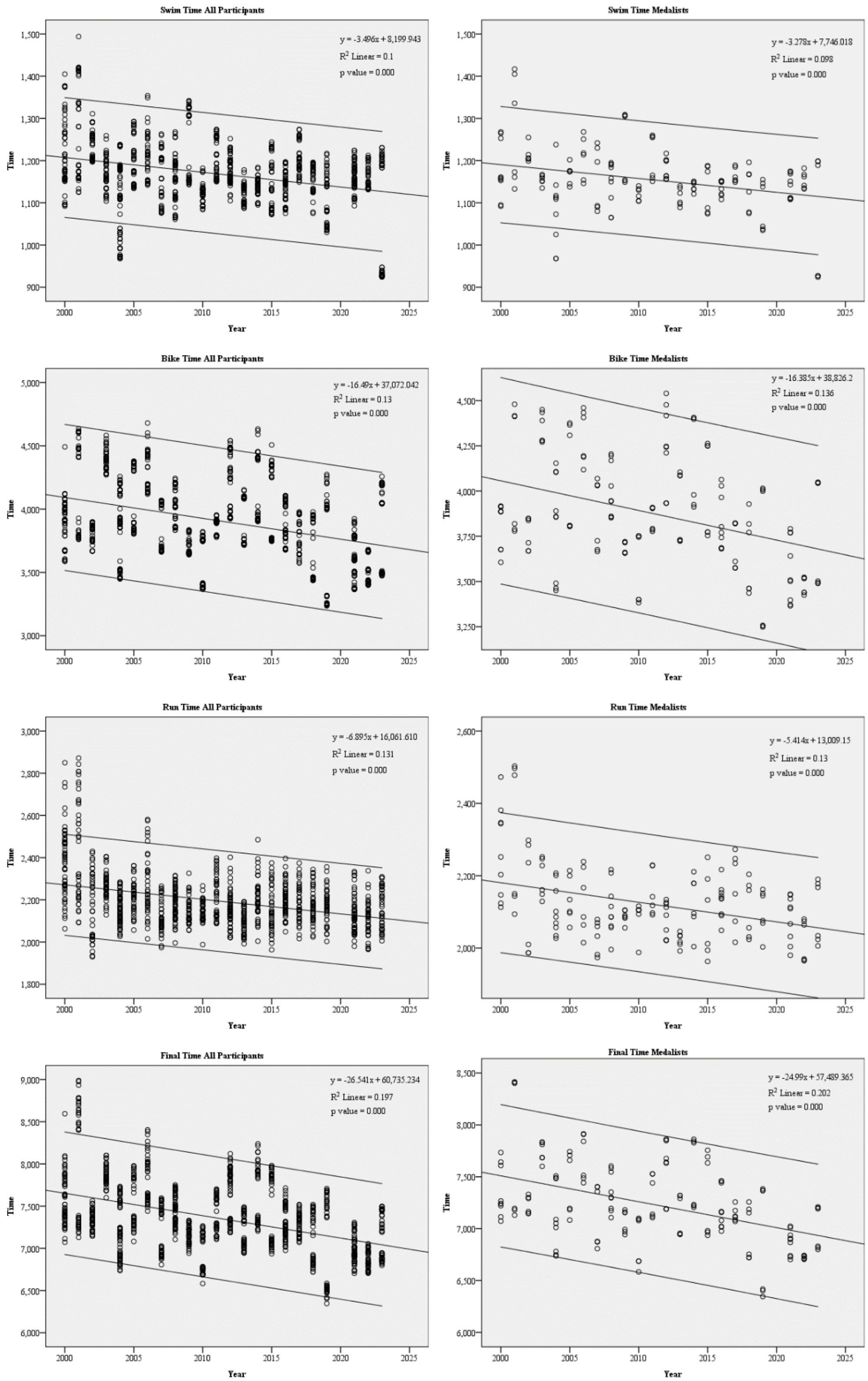

Figure 3. Time evolution (seconds) for medalists and all athletes throughout 23 years. Regression equation; R^2: Coefficient of determination. P value.

DISCUSSION

One of the aims of the present study was to compare performance levels across main triathlon events. Swimming time is the only discipline that remains consistent across all competitions for non-medalists and medalists (p values 0.325; 0.840) (Table 1). The First transition phase at the Olympic Games is significantly lower than the World Championship or European Championship (p values <0.001 / η^2 0.205; 0.152) (Table 1). An interesting finding is that medalists perform the same at the Olympic Games and World Championship, except for the just mentioned First transition phase. This could be attributed to a potentially shorter setup for the transition area at the six Olympic Games, possibly designed to enhance the overall spectacle. Cycling time reveals a significantly better performance at the World Championship in comparison with the rest of the competitions for non-medalists (p values <0.001 / η^2 0.061), but only with the European Championship when analyzing only the medalists (p-value <0.01 / η^2 0.060) (Table 1).

The best time never corresponds to the European Championship for any group. This is reasonable as it is considered the least significant competition among those analyzed. In Cycling, Running, and Final times, the best times correspond to the World Championship (Table 1). The importance of the World Championship and the Olympic Games is roughly similar, and the better values in the World Championship may be attributed to a larger sample size, consequently providing athletes with more experience and opportunities to perform optimally in each discipline.

Another goal of this study was to compare the performance of medalists with that of the non-medalists. No significant differences between medalists and non-medalists have been found for performance in the Transition phases. Swimming time showed significant best times at the two main competitions, the Olympic Games and the World Championship (p values <0.05; <0.01 / d 0.620; 0.364) (Figure 2).

Cycling time only showed significant differences at the Olympic Games (p-value <0.05 / d 0.483). Therefore, the community should be cautious when confirming that this discipline is a substantial difference between medalists and non-medalists. In fact, Piacentini et al. (2019) (4) have already stated that cycling is a transition towards running. This means there is little tactic involved in the cycling discipline other than maintaining a good position within a good race group (Figure 2). One of the reasons may be that cycling performance in triathlon is related to the ability to perform intermittent high efforts (40), and the circuit layouts that favor the show and the drafting may limit triathletes' ability to optimize their performance fully.

An important finding is that Running and Final times reveal significant differences favoring medalists at all competitions (p values <0.001 for Running time at all competitions) (p values <0.001; <0.001; <0.01 for Final time at the Olympic Games, World Championship and European Championship respectively) (Figure 2). Running time always had the most significant effect size in every competition (d 1.630; 0.735; 0.764 for the Olympic Games, World Championship, and European Championship, respectively). These values highlight that Running time is the most important difference between the medalists and the rest, although not the only one, playing a crucial role in achieving a better overall performance.

A significant relationship exists between the years and performance for all disciplines, considering both medalists and all athletes (p values <0.001 for both groups and all disciplines) (Figure 3). It can be stated that over the years, performance has improved in all disciplines. This finding aligns with Wonerow et al., (2017) (38), who stated that both women and men improved their performance in most age groups over the years, and also with García-González and González-Jurado (2024) (41), who reached a similar conclusion for male triathletes. Previous studies (42) have conducted similar research in swimming and reported findings consistent with this study, and other studies have focused on the COVID-19 pandemic (32, 33). Similarly, other authors emphasized the study of running performance evolution (43, 44), which also matched the findings of this study.

One of the main reasons for this performance development may be the technological advancements experienced in sports, as shown by some researchers (45). The development of smartwatches and the increasing sales of heart rate monitors over the years highlight the growing popularity of technology in sports. The technical possibilities for this technology to be applied to triathlons continue to increase (46). Considering that our current smartwatches track physiological parameters such as heart rate, heart rate variability, heart rhythm, pulse wave, respiratory rate, oxygen saturation, and sleep quality (46), plus the outbreak of Artificial Intelligence, the potential is endless.

Due to the anomalous format of the World and European competitions in 2020, added to the non-participation of several athletes, this data were excluded from the analysis as it did not fit the format observed in the rest of the years. The present study has some limitations. Firstly, there is a minimal amount of missing values not published by the ITU, which were not included in the analysis. Moreover, this study adopts a quantitative approach, which implies a lack of consideration for physical or other nature-related variables, such as circuit layout or climatic conditions. Some recent literature already incorporates analysis considering altitude, temperature, and the type of water in the swimming discipline (47). The descriptive design does not provide insight into the underlying explanations for performance improvement, although it suggests some potential reasons. However, the authors suggest that, in addition to key advancements in nutrition, training, and biomechanics, the increasing popularity of triathlon, as evidenced by a rise in the number of sports licenses, has also played a significant role. These limitations should be considered when interpreting the findings, as they may introduce potential biases in performance assessment.

Future articles should consider incorporating physiological measures. It is also advisable for future researchers to focus on comparing the competition. There is a lack of literature on this topic, and it may be helpful for coaches and athletes to identify target competitions. There is extensive literature comparing distances since physiological differences are more pronounced.

CONCLUSION

From the findings of this study, it can be concluded that Running time is the most differentiating discipline between top-class female triathlon medalists and the rest of athletes, although is not the only one. Nevertheless, the swimming and cycling times are also significantly better in specific competitions. Furthermore, a causal relationship has been demonstrated between the years and the performance improvement in all disciplines, being similar for medalists and all participants. Last but not least, the performance comparison between competitions shows variable results, but it is noteworthy that Swimming time remains nearly consistent regardless of the competition. Furthermore, Cycling, Running, and Final times are superior at the World Championship compared to the Olympic Games and European Championship. Therefore, it is fair to say that female triathletes perform better at the World Championship than in other competitions.

APPLICABLE REMARKS

- The findings of this study contribute to the development of triathlon and female athlete training by providing a comprehensive longitudinal analysis of Olympic-distance triathlon performance, highlighting the predominance of specific disciplines. The results enable coaches and athletes to optimize training strategies by considering seasonal performance trends and competitive targets. Additionally, the comparison between medalists and non-medalists offers insights into the performance required for podium finishes, which may also aid in early-career talent identification.

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AUTHORS' CONTRIBUTIONS

Study concept and design: José Antonio González Jurado. Acquisition of data: Pablo García González. Analysis and interpretation of data: Pablo García González. Drafting the manuscript: Pablo García González. Critical revision of the manuscript for important intellectual content: José Antonio González Jurado. Statistical analysis: Pablo García González. Administrative, technical, and material support: Pablo García González. Study supervision: José Antonio González Jurado.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

FINANCIAL DISCLOSURE

There are no financial interests related to the material in the manuscript.

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The authors did not receive any financial support for the research.

ETHICAL CONSIDERATION

Informed consent from each patient included in the study was not necessary, as the data is public on the International Triathlon Union website.

ROLE OF THE SPONSOR

There are no sponsors for this study.

ARTIFICIAL INTELLIGENCE (AI) USE

AI or AI-assisted tools were not used in this study.

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