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The beginning of success: Performance trends and cut-off values for junior and the U23 triathlon categories

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ABSTRACT

Background: This study sought to determine cut-off values for each triathlon discipline to achieve podium in Junior (short distance; 750 m swim, 20 km cycle and 5 km run) and U23 (standard/Olympic distance; 1.5 km swim, 40 km cycle and 10 km run) triathlon events. Additionally, we aimed to investigate which discipline has the largest relationship with overall Junior and U23 triathlon performance, and the effect of sex and time in performance trends.
Methods: We included all data from Junior and U23 official races (International Triathlon Federation; ITU) of Junior (n = 3,314 finishes) and U23 (n = 5,092 finishes) categories held from 1999 to 2018.
Results: Men were significantly faster than women in both Junior (11.13%) and U23 (12.28%) categories. Swimming and cycling times were faster in 2009-2018 than in the 1999-2008 decade for men (3.36%; 6.49%), women junior (6.50%; 7.09%), men (0.15%; 3.46%) and women U23 (1.61%; 3.31%) respectively. Cycling was the discipline with the greatest influence on overall triathlon performance in Junior and U23 categories, regardless of sex or rank position. The cut-off values for the Junior category were (men/women): swimming, 9.2/9.4 min; cycling, 31.9/38.2 min; running, 16.8/18.9 min. U23's cut-off values were (men/women): swim, 18.0/19.4 min, cycling: 63.4/70.1 min; run, 33.9/38.7 min.
Conclusion: Cycling was the discipline with the greatest influence on overall performance for both men and women in Junior and U23 categories. Moreover, swimming and cycling performances increased over the years for both sexes.

1. Introduction

Triathlon is an endurance sport that combines three different disciplines (swimming, cycling, and running) over a variety of distances. The sport first appeared at the end of the 1970s and, the number of practitioners has grown since then.[1,2] The performance of the triathlon has been studied for a long time, since different research groups have already analyzed several aspects, among which the following stand out: physiological,[3–5] biomechanical,[6,7] training.[8,9] However, all these studies were conducted with adult categories (over 23 years old), which carry out tests by the Ironman organization, with half distance (1.9 km of swimming; 90 km of cycling and 21 km of running) or full (3.8 km of swimming; 180 km of cycling and 42,195 km of running).

It is well-known that the morphophysiological characteristics partially explain the faster performance in men than women in all

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triathlon distances.[10,11] However, new evidence has shown that women have narrowed the gap in ultra-triathlon.[12,13] As seen at the Ironman World Championship in 2018, where the fastest woman finished overall 25th place, ahead of over 50 elite men.[14] In addition, for both sexes, faster swimming promotes an advantage in cycling, as finishing the swim together with the leadership group can reduce the levels of central and peripheral fatigue caused by the influence of draft on cycling. Draft in triathlon is when an athlete rides closely behind another athlete, which considerably reduces the wind resistance and saves energy. In draft-allowed triathlon events, athletes usually adopt a strategy to swim fast to be able to do the cycling within a group, thus saving energy for the running leg.[2,15,16]

In turn, the ITU (International Triathlon Union) is the competent body for the promotion of sport worldwide. In events regulated by such an organization, there is a division of categories, such as Junior (aged between 16 and 19 years old) who compete in Sprint distance (750 m swimming; 20 km cycling; 5 km running); U23 (aged between 19 and 23 years old); and Elite (age over 23 years); Elite and U23 compete in Olympic distance, also known as Standard triathlon distance (1.5 km of swimming; 40 km of cycling; 10 km of running).[17]

As it is a sport of different disciplines, there is a significant energy expenditure, due to the high intensity maintained by athletes. Therefore, the distribution of work or energy expenditure during the race is of fundamental importance to keep performance optimization.[18] The relationship between energy expenditure and speed distribution is defined as pacing, a term widely used in endurance competitions. Understanding pacing during triathlon competitions can be relatively complex, as athletes not only distribute their efforts throughout the whole race, but also for each discipline independently. That is because the strategy can vary significantly during swimming, cycling and running.[19]

Gadelha et al.[20] determined the cut-off points for the Olympic event in elite athletes. In other words, specific race time performance points calculated based on previous race results that indicates a higher chance of medal. The study showed specific cut-off points for male and female elite athletes by each (triathlon) discipline, allowing forthcoming elite athletes to have a performance reference to be successful. Despite the relevance of this model, there are no studies for younger triathlon categories, such as Junior and U23. Adapting the training routine with specific goals would significantly increase the chances a young athlete to become a champion in the elite category.[21–23] In addition, performance trends have being conducted for a wide range of triathlon distances and events, contributing to sport science and allowing researchers, coaches and athletes to better understand performance in different contexts (decades, sex, age, nationality).[14,24,25] However, there are no studies investigating the performance trends of triathletes in Junior and U23 categories.

In this context, optimal pacing goals for each discipline may be of great assistance for athletes and coaches (especially in Junior and U23) willing to achieve success in ITU's races. To the best of our knowledge, there is a lack of evidences regarding early categories (i.e., Junior and U23), gender differences, and/or performance trend analyses. Therefore, the aims of the present study were: (i) to determine cut-off points of performance to success (being among the medal group) from each discipline in Junior and U23 triathlon races; (ii) to investigate which discipline has the more considerable influence in overall result in Junior and U23 categories; and (iii) to analyze the performance trends in Junior and U23 divisions in the latest two decades.

2. Methods

This study was approved by the Institutional Review Board of Kanton St. Gallen, Switzerland, with a waiver of the requirement for informed consent of the participants as the study involved the analysis of publicly available data.

2.1. Subjects

All data were the official results of the World Triathlon Series (WTS) events from 1999 to 2018. Data were collected of the Olympic/standard (1.5 km/0.93 mile of swimming; 40 km/24.9 miles cycling; and 10 km/6.2 miles running) for U23 and sprint (0.75 km/0.46 mile swimming; 20 km/12.4 miles cycling; 5 km/3.10 miles running) for Junior. Events with different distances from the standard (i.e., changed due to technical or environmental issues: reduced distance, swim exclusion) were excluded from the analysis. Data were split and compared the decades of events (1999–2008 and 2009 to 2018) for men and women.

The U23 category had an age range from 19 to 23 (mean and SD: 21 ± 2) years old, being 2,225 men and 1,089 women (n = 3,314). The Junior category included athletes aging from 15 to 19 years (mean and SD: 17 ± 2), with 3,196 men and 2,706 women (n = 5,092). All performance data (overall, swim, cycle, and run times) were transformed into minutes and analyzed. The total sample size was 8,406 finishers.

2.2. Statistical analyses

Continuous data had normality and homogeneity assessed with Kolmogorov-Smirnov's and Levene's test, respectively. Since all continuous variables presented parametric distribution, data were expressed and mean and standard deviation (±). Performance trends were analyzed using linear regressions. Performance trends with just the top-3 of each race in each year were also performed. A student *t*-test for independent samples was used to compare the times of men and women. Multivariate analysis with overall race time and the dependent variable was performed to assess which split may have a greater influence.

Further, sensitivity, specificity, positive and negative likelihood ratio, odds ratios, and confidence intervals (95%) for the podium position considering the cut-off value (ROC curve) for the top-3 rank position were calculated. Receiver operating characteristic (ROC) analysis was adopted to select the cut-off points that identified the podium for each discipline of triathlon. For this procedure the sample was divided into a total group and a subgroup comprising just the winners (podium). Briefly, a ROC curve is generated by plotting sensitivity on the y-axis as a function of [1 - specificity] on the x-axis. Sensitivity is the percentage of individuals who exhibited the outcome (in the case studied here, podium subjects) and who have been correctly diagnosed by the indicator in question (i.e. true positives), while specificity describes the percentage of individuals who did not exhibit the outcome and were correctly diagnosed by the indicator (i.e. true-negatives). The criterion utilized to choose the cutoff points was to select the values

Table 1
Overall and split race times of triathlon race performance of Junior and U23 categories from 1999 to 2018. Data expressed as mean (±standard deviation).

	Junior Men (n = 3,196)	Junior Women (n = 2,706)	U23 Men (n = 2,225)	U23 Women (n = 1,089)
Overall (min)	61.60 (5.34)*	68.46 (6.20)	117.47 (7.74)*	131.90 (8.77)
Swim (min)	10.16 (1.78)*	11.02 (1.95)	19.02 (2.42)*	20.82 (2.42)
Cycle (min)	32.08 (3.68)*	35.41 (4.26)	61.41 (4.90)*	69.36 (5.70)
Run (min)	18.03 (2.23)*	20.44 (2.46)	35.78 (3.96)*	40.29 (4.03)

*: differences between groups $p < 0.001$.

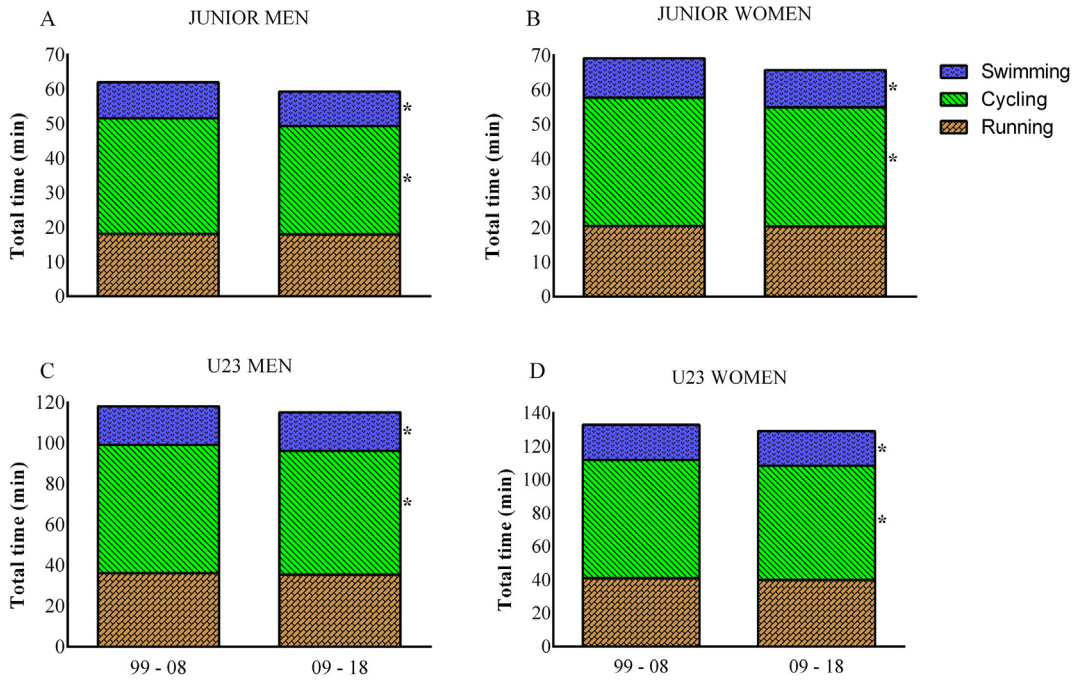

Fig. 1. Average race times of each discipline (swim; cycle; run) across two decades of Olympic distance triathlon in men and women. *: differences between groups $p < 0.05$.

at which sensitivity and specificity were most similar and were not less than 60%. The statistical significance of each analysis was verified by the area under the ROC curve and by the 95% confidence interval (95%CI). Thus, a perfect indicator would offer an area under the ROC curve of 1.00, while a diagonal line would represent an area of 0.50. For an indicator to be exhibiting any discriminative power its area under the ROC curve must be between 0.50 and 1.00, and the greater the area the greater the indicator's discriminative power. The curve analysis allowed us to set cut-off values in minutes (later converted to race pace/speed) for each discipline and overall

Table 2
Multivariate regression results to determine discipline influence in Sprint and Olympic triathlon altogether and clustered by race ranking.

	R	R^2	R^2_{adj}	*p*-value	Coefficients		
					Swim	Cycle	Run
Junior men							
All athletes (n = 3,196)	0.976	0.952	0.952	<0.001	0.236	0.702	0.381
Top 3 (n = 193)	0.948	0.900	0.898	<0.001	0.243	0.776	0.320
≥4th (n = 3,003)	0.976	0.953	0.953	<0.001	0.238	0.707	0.375
Junior women							
All athletes (n = 2,282)	0.987	0.975	0.975	<0.001	0.294	0.702	0.374
Top 3 (n = 199)	0.982	0.964	0.963	<0.001	0.357	0.672	0.374
≥4th (n = 2,083)	0.988	0.975	0.975	<0.001	0.292	0.712	0.364
U23 men							
All athletes (n = 2,087)	0.993	0.987	0.987	<0.001	0.302	0.619	0.510
Top 3 (n = 206)	0.994	0.989	0.989	<0.001	0.364	0.587	0.504
≥4th (n = 1,881)	0.993	0.986	0.986	<0.001	0.298	0.627	0.504
U23 women							
All athletes (n = 1,089)	0.993	0.987	0.987	<0.001	0.274	0.633	0.470
Top 3 (n = 192)	0.994	0.988	0.988	<0.001	0.358	0.611	0.504
≥4th (n = 897)	0.993	0.986	0.986	<0.001	0.260	0.644	0.457

Overall race time (min) was used as dependent variable for all analysis; Top 3: the top three athletes in a single event; ≥ 4th: all athletes in a single event that finished fourth and below.

Table 3
Multivariate regression results to determine discipline influence in Sprint (Junior) and Olympic (U23) triathlon as across two decades in men and women.

	R	R^2	*p*-value	Coefficients		
				Swim	Cycle	Run
Junior men						
1999-2008	0.967	0.936	<0.001	0.258	0.825	0.314
2009-2018	0.980	0.960	<0.001	0.246	0.598	0.445
Junior women						
1999-2008	0.981	0.962	<0.001	0.293	0.809	0.311
2009-2018	0.991	0.982	<0.001	0.315	0.593	0.449
U23 men						
1999-2008	0.989	0.979	<0.001	0.158	0.594	0.511
2009-2018	0.995	0.991	<0.001	0.358	0.626	0.528
U23 women						
1999-2008	0.992	0.984	<0.001	0.172	0.608	0.483
2009-2018	0.994	0.989	<0.001	0.321	0.646	0.479

Overall race time (min) was used as dependent variable for all analysis.

race time to achieve a Top-3 rank in both Junior and U23 for men and women.

The significance level was 5% ($p < 0.05$). All procedures were performed using Statistical Software for the Social Sciences (SPSS v21.0, Chicago, IL, USA) and GraphPad Prism (Prism v6.0, San Diego, CA, USA).

3. Results

Men were significantly faster than women in all disciplines and overall performance both in Junior (swim: mean difference 0.86 min, $p < 0.001$; cycle: 3.33 min, $p < 0.001$; run: 2.41 min, $p < 0.001$; overall: 6.86 min, $p < 0.001$) and U23 (swim: 1.86 min, $p < 0.001$; cycle: 7.95 min, $p < 0.001$; run: 4.51 min, $p < 0.001$; overall: 14.93 min; $p < 0.001$). See Table 1.

Junior and U23 men and women were faster swimmers and

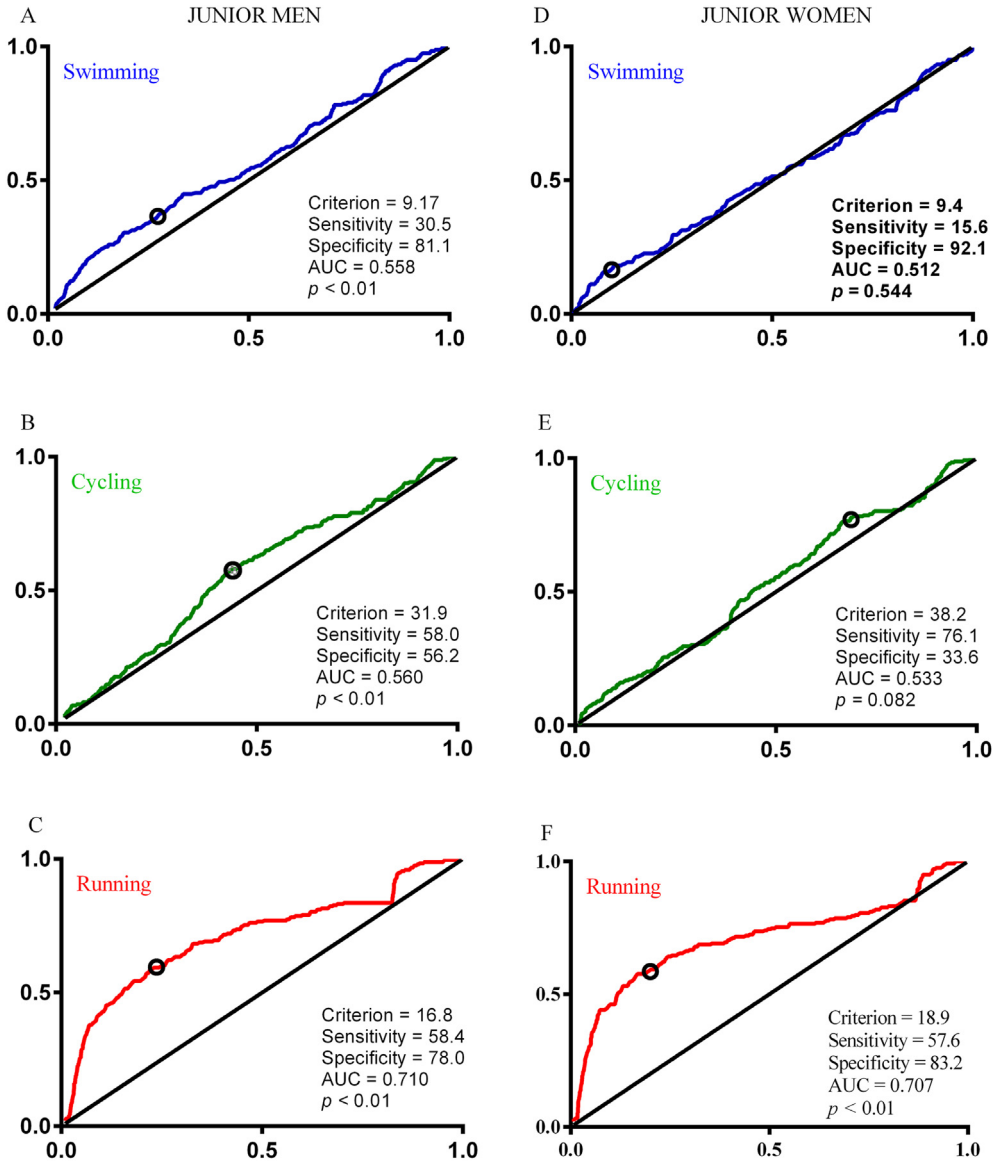

Fig. 2. Receiver Operating Characteristic curve (sensitivity: y-axis; specificity: x-axis) according to the top-3 male and women rank position of each trait of triathlon junior; AUC = area under curve.

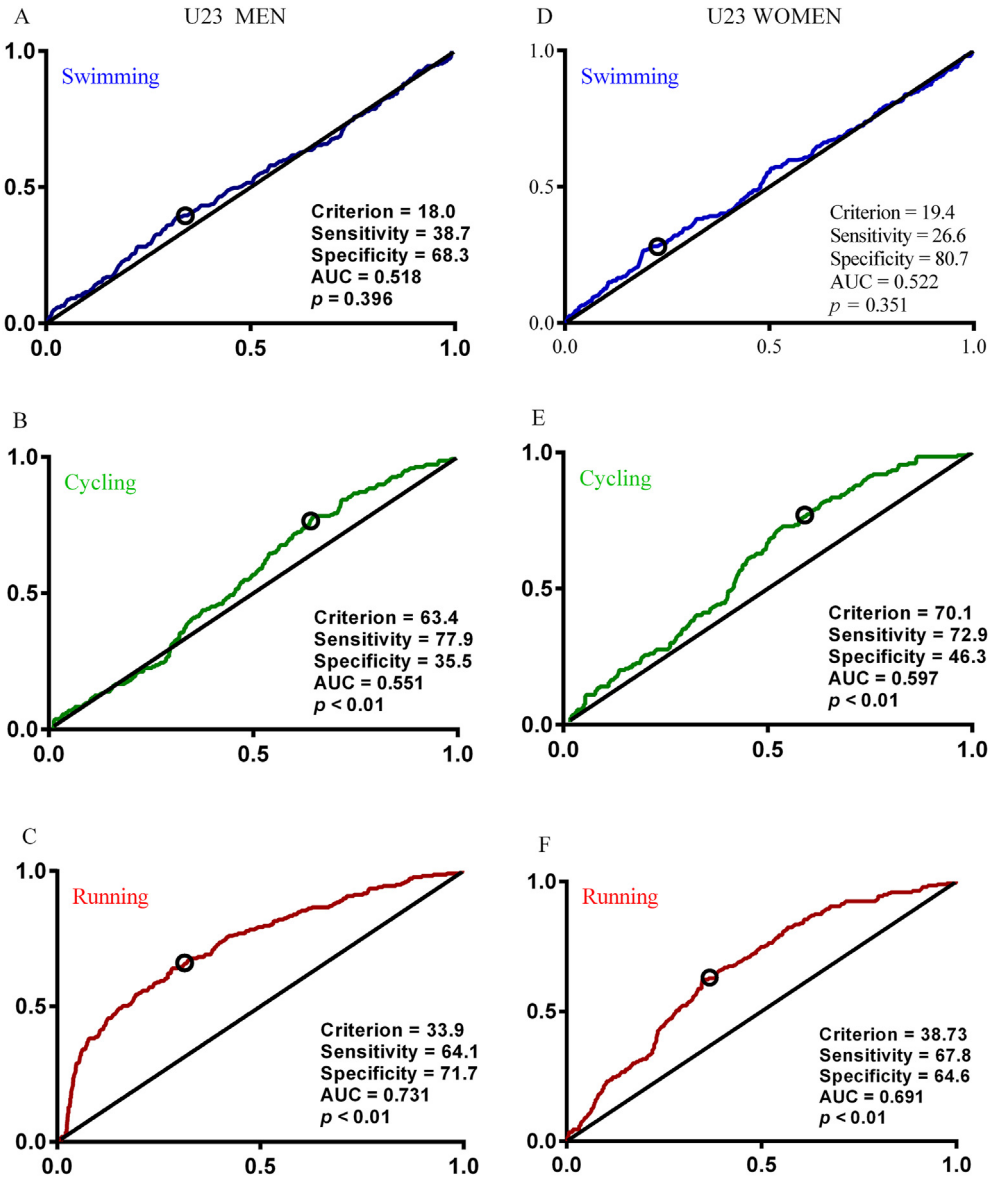

Fig. 3. Receiver Operating Characteristic curve (sensitivity: y-axis; specificity: x-axis) according to the top-3 men and female rank position of each trait of triathlon U23; AUC = area under curve.

cyclists in the last decade ('09 – '18) in comparison to the previous decade ('99 – '08). However, no performance improvement was identified for the running discipline (Fig. 1).

The multivariate regression analysis showed that cycling is the discipline with the greatest influence on overall race time for both men and women Junior and U23, and with the sample divided in Top-3, ≥4th place, or altogether (Table 2). Swimming is the discipline with the least influence on overall race time for both sexes regardless of the category and rank position. Running showed to be the second most influential discipline for overall performance in sprint and Olympic distance races for men and women of both categories.

The multivariate regression carried out in different decades showed that cycling had a greater influence in overall race time for both men and women in the two decades, and swimming was the less influential, followed by running (Table 3).

In the Junior category, the cut-off values (and 95% confidence interval; CI) for men were: swim: 9.17 min, average pace (AP): ~1:14min/100 m; 1:11min/100yrd, odds ratio (OR) = 1.88; cycling: 31.9 min, average speed (AS): ~36.9 km/h; ~24.6mph, OR = 1.77; run: 16.8min, AP: ~3:29 min/km; ~5: 29/mile, OR = 4.97. And for the women: 9.38min, AP: ~1:17min/100 m; ~1:16min/100yrd, OR = 2.15; cycling: 38.2min, AS: ~31.3 km/h; ~20.8mph, OR = 1.61; run: 18.9min, AP: ~3:53 min/km; ~6:08min/mile, OR = 6.75 (Fig. 2).

U23's cut-off values for men were: swim: 18.03 min, AP: ~1:12min/100 m; ~1:11min/100yrd, OR = 1.36; cycling: 63.4 min, AS: ~37.7 km/h; ~24.6mph, OR = 1.94; run: 33.9min, AP: ~3:27 min/km; ~5:29min/mile, OR = 4.51. And for the women: swim: 19.4 min, AP: ~1:18min/100 m; ~1:16min/100yrd, OR = 1.53; cycling: 70.1min, AS: ~34.1 km/h; ~20.8mph, OR = 2.35; run: 38.7min, AP: ~3:55 min/km; ~6:08min/mile, OR = 3.86 (Fig. 3).

Finally, the cut-off values for overall performance were: Junior men: 62.3 min (2.46–4.48), OR = 3.32; Junior women: 66.6 min, OR = 2.51; U23 men: 115.7 min, OR = 2.84; U23 women: 128.7 min, OR = 3.09 (Fig. 4).

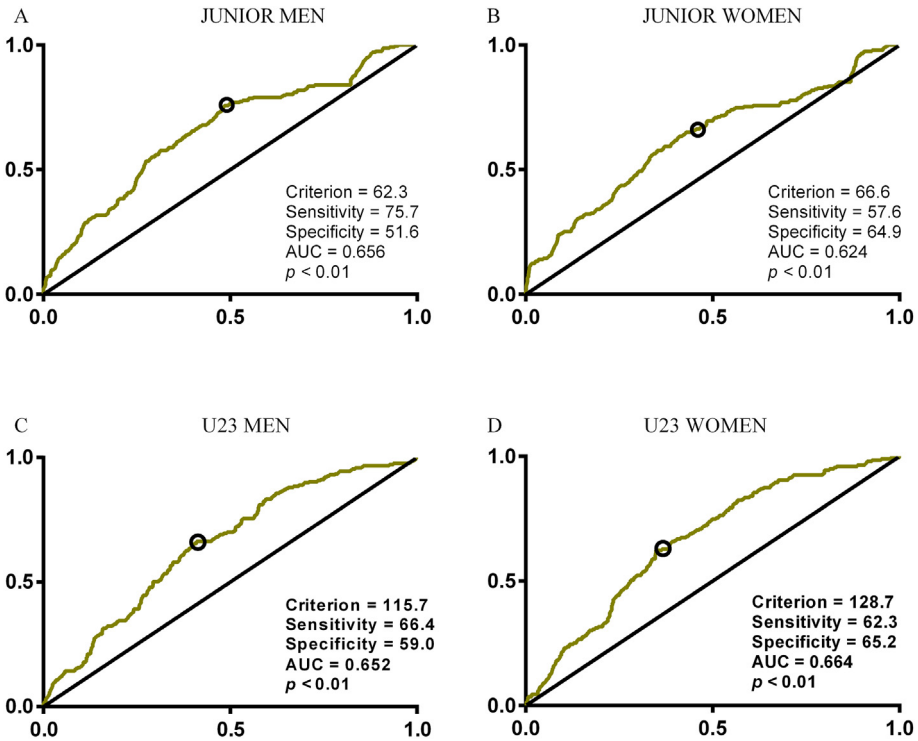

Fig. 4. Receiver Operating Characteristic curve (sensitivity: y-axis; specificity: x-axis) according to the top-3 men and female rank position of each trait of triathlon junior and U23 of overall time; AUC = area under curve.

4. Discussion

This study sought to determine cut-off values from each triathlon discipline to achieve success (rank top3) in a Junior or U23 triathlon race. Athletes who perform with race times below the cut-off points have a significantly higher chance for sporting success (achieve top-3 rank) when compared to others. Additionally, the main finding was that cycling is the most influential discipline to overall performance for both Junior and U23 and that athletes have improved their swimming and cycling performance from one decade (99-08) to the other (09-18). These results provide support for the gender-specific cut-off values which have technical implications and might be useful evidence to training strategies for both Junior and U23 categories.

The cut-off values may be of great assistance for coaches and athletes willing to achieve a top-3 rank position for Junior and U23 WTS races. Coaches can use pace/speed parameters to determine training goals, identify weaknesses and young talents. An athlete able to perform in an even or better pace/speed than the cut-off point means a higher chance to climb the podium after the race. Cut-off points for elite men and women racing the WTS circuit were also pre-established and may also serve as a parameter for Junior and U23 athletes. However, the difficult level in a racecourse, environmental conditions, and rivalry are also considerable factors to determine an athlete's strategy and pace goal.[26]

Regarding the most influential discipline to overall performance, the results were surprising. Cycling is the discipline the comprehends the longer portion of time in any triathlon distance[13,27,28] and is a surprise that it also is the most determinant discipline to overall performance in full-length triathlon distance.[14,29] However, the evidence for triathlons in standard/Olympic distance shows that cycling is the least influential discipline to overall result.[26,30,31] An interpretation of this discrepancy might be the race regulations that allow or disallow drafting during the cycling, leading to the formation of cycling packs, making the running discipline the most influential.

Although race regulations for short distance Junior races and standard distance U23 races are the same as the Elite category, the most influential discipline is not. We believe that the high heterogeneity (different performance levels in the three disciplines) and the reduced number of athletes in Junior and U23 categories leads to smaller cycling packs (two to five athletes). Thus, this increases competitiveness during the cycling split, since there is a higher chance of athletes to bridge to the next small pack, or be reached by a chasing pack. Conversely, in elite WTS races there usually one or two big cycling packs (20-30 athletes in each one), and athletes often just try to keep up with the pack and save energy for the running leg, making it less competitive in comparison to Junior, U23 or Ironman races.[32]

The performance increases in swimming and cycling from the past to the present decade might be for two possible reasons. One is due to technology improvement in road cycling, reducing bike weight, drag, and increasing aerodynamics.[14,29] An enhancement in sports science literature and training apparatus could influence both disciplines.[33] Additionally, a change of race strategy should also be considered, with athletes aiming to perform a faster swim to be able to cycle with the quicker cyclists and increase their chances of success in overall performance.

The sex differences in the present study showed that men are faster than women in Junior and U23 categories in all disciplines. This trend corroborated with previous research in elite athletes in the standard distance,[30] full-length triathlon[34] and ultra-triathlon.[35] Men have an elevated expression of sex-specific genes that leads to a higher secretion of sex-specific hormones, making them have more muscle mass and more red blood cells.[36] Consequently, men have increased muscle power and increased aerobic capacity (VO_2max and running economy).[10,37] However, it is of note the women are closing the performance gap in ultra-endurance

sports, especially open-water swimming.[38,39] This analysis is the first to establish the performance cut-off points to success (achieve top-3 rank) for each discipline in Junior and U23 triathlon races.

4.1. Limitations of study

The study has some relevant limitations that can be inserted in future research, such as climatic factors (dry/wet bulb temperature, altitude, etc.) that may interfere with the performance of the three modalities separately and, consequently, the final time, in addition. Furthermore, transition times (T1: swimming to cycling and T2: cycling to running) were not included, as the main objective of the present study was to determine cutoff points for performance in triathlon modalities in the Junior and U23 categories.

5. Conclusions

Men are faster than women in both short and standard distance triathlon in Junior and U23 categories. Swimming and cycling performances have increased over time. Additionally, cycling is the discipline with greater influence on the overall result for both men and women in Junior and U23 categories. Finally, the performance cut-off points were set and may be useful for athletes and coaches to establish training and pacing goals and improve their chance of success.

Author statement

All authors contributed to the manuscript and agree with its publication in the present form

Declaration of competing interest

The authors declare no conflict of interest.

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