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Finding the fastest race locations for non-elite IRONMAN® age group triathletes

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Abstract

Introduction. The IRONMAN® triathlon is particularly interesting for recreational (age group) triathletes, where tens of thousands compete annually to qualify for the IRONMAN® World Championship in Hawaii. Aim of Study. The purpose of the present study was to identify the fastest event location for age group triathletes. Material and Methods. A total of 687,662 finisher records of IRONMAN® age group triathletes from 446 events at 65 different locations between 2002 and 2022 were analyzed, aggregating records by location and calculating and displaying descriptive statistics. The statistical significance of the differences observed was tested using a two-way ANOVA (sex and event location as independent variables, overall race times or split times as dependent variables) and post-hoc Tukey's HSD tests. Results. The fastest swim times were achieved in IRONMAN® New York, ahead of IRONMAN® Switzerland Thun and IRONMAN® Chattanooga for both men and women. There were differences between women and men regarding the fastest cycling and running courses. The fastest cycling splits were in IRONMAN® Barcelona, followed by IRONMAN® Copenhagen and IRONMAN® Tallinn for men and IRONMAN® Barcelona, IRONMAN® Copenhagen and IRONMAN® Vitoria-Gasteiz for women. For the marathon, men achieved the fastest running split in IRONMAN® Hawaii, ahead of IRONMAN® Vitoria-Gasteiz and IRONMAN® Tallinn, whereas women were the fastest in running in IRONMAN® Gdynia, IRONMAN® Haugesund Norway and IRONMAN® Hawaii. For overall race times, men achieved their times in IRONMAN® Hawaii, followed by IRONMAN® Vitoria-Gasteiz and IRONMAN® Copenhagen. For women, the fastest overall race times were achieved in IRONMAN® Vitoria-Gasteiz ahead of IRONMAN® Hawaii and IRONMAN® Copenhagen. For overall race times, average water temperatures were at 20.7 ± 2.8 °C and average air temperatures at 23.0 ± 3.0 °C. Most swimming courses were in a lake (7/10), most cycling courses were rolling (6/10) and most running courses were flat (7/10). Conclusions. Despite differences regarding the event locations, the fastest race courses were identified in the USA and Spain.

KEYWORDS: endurance, exercise, environment, performance.

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Introduction

Non-professional sports practice has increased in recent years at an international level [30, 31].

Mass events, including running, cycling, and swimming, have been a potential strategy to improve well-being, health, and social aspects [12, 31], especially in an outdoor space, increasing contact with the natural environment [22].

Participation trends in triathlon events showed an increase over the last few years, with the peak of participation among the non-elite population achieved in the last decade [44]. These participation trends in triathlon events such as IRONMAN® triathlon, have motivated researchers to conduct investigations related to athletes' health [19], performance [25] and sport management, sponsorships, and economics [28]. However, no studies assessing the IRONMAN® triathletes' performance by event location have been found so far, especially not for the very large group of IRONMAN® age group triathletes.

Competing in triathlon races, such as the IRONMAN® triathlon, involves dedicating more time and routine organization to the training demands associated with work, social and family life [24, 38]. In this sense, due to their importance in relation to the optimization of training and competition, studies related to performance have increased in recent years [5, 39].

Among the variables generally evaluated, physiological characteristics have been considered essential to improve performance in endurance activities, with differences between the sexes [14, 32, 45]. Thus, the evaluation of training and the domains of variables for triathletes would be related to the requirement to sustain a higher intensity for a prolonged period of training. In addition, training, sleep, previous experience, and nutritional factors were also highlighted as important factors to be considered [11, 15, 38].

Knowing that these factors are associated with the fact that performance would be a complex activity resulting from the interaction of environmental factors, the effect of these factors in maximizing performance was considered. Among these, environmental factors can be studied from different perspectives, including social and financial support, training facilities, competition, and characteristics of host countries [30, 43]. As mentioned, studies regarding environmental factors with IRONMAN® triathletes have been directed at physiological issues, however, the physical and natural environment, such as climatic characteristics, could negatively affect performance [2, 20, 27].

Alternatively, no data are available regarding the role of the event location in the performance, especially for IRONMAN® age group triathletes. The IRONMAN® triathlon is particularly interesting for recreational (age group) triathletes, where tens of thousands compete annually to qualify for the IRONMAN® World Championship in Hawaii. Since IRONMAN® triathletes must qualify for the IRONMAN® World Championship by competing in races worldwide, they need to know where the fastest race times can be achieved. The influence of the event location can be considered from different perspectives, including topography (e.g., elevation changes, hills, slopes), weather characteristics (e.g., wind velocity, humidity), and natural elements (open water swims in lakes, oceans, or rivers), that will demand specific skills of the participants. The protocols to qualify for the IRONMAN® World Championship race include finishing at or towards the top of one's age group depending on how many slots are allocated for each age group. Thus, the completion time is of little consequence. The benefit of knowing which courses have the fastest times for each discipline of competition is so an athlete could potentially choose a course that minimizes the impact of their weak discipline. For example, a slow swimmer who is a very strong cyclist and runner might want to choose a course that has a faster swim and is wetsuit legal. In addition, non-elite IRONMAN® participants in these events might invest a high quantity of financial resources and physical effort during training preparation and travel to the event location.

To address the knowledge gap regarding the influence of environmental factors associated with performance in non-elite triathletes of both sexes, we aim to identify the fastest IRONMAN® event location for non-elite IRONMAN® triathletes. The findings will be helpful for athletes and coaches to find the fastest race course in order to achieve a personal best race time.

Material and Methods

Ethical approval

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 (EKSG 01/06/2010). The study was conducted in accordance with recognized ethical standards according to the Declaration of Helsinki adopted in 1964 and revised in 2013.

Data set and data preparation

The race data was downloaded from the official IRONMAN® website (www.ironman.com) using a Python script. The athletes' sex, age group, country of origin,

event location and year, and times for swimming, running, cycling, and transition times 1 (swimming to cycling) and transition times 2 (cycling to running) were thus obtained. We also obtained environmental characteristics such as race course description for swimming, cycling, and running and weather data such as water and air temperature, which was merged with the race data. Data were inspected for consistency, removing duplicate and/or incomplete records. Especially all race results from IRONMAN® North Carolina had to be removed. IRONMAN® North Carolina was held only once (22 October 2016), and while the swim and the run were typical IRONMAN® distances, the bike course was only 56 miles (half the distance), which accounts for both the low participant numbers and the fast times [4]. Likewise, the event location variable was harmonized to map generic and free-format values to their actual locations. After pre-processing the raw data, the resulting dataset consisted of 687,662 age group IRONMAN® finisher records covering 446 events between 2002 and 2022 across 65 different event locations.

Statistical analysis

The race records were aggregated by location, and then the statistical values (mean, std, max and min) of split and full finish times were calculated for each location. The results are presented using strip plots that graphically show the distribution of full and split times in each location, along with detailed tables with the descriptive statistical values, for men and women separately. Both tables and charts are sorted by mean race times to easily identify the fastest locations. Approximate normal distribution of the target variable was assessed by plotting histograms of full race and split times. The statistical significance of the performance differences was tested using a two-way ANOVA (sex and event location as independent variables, overall race times or split times as dependent variables) and post-hoc Tukey's HSD tests. The significance level was set at 0.05 in all cases. All data processing and analysis were performed using Python (www.python.org/) and a Google Colab notebook (https://colab.research.google.com/).

Results

A total of 687,662 finisher records of IRONMAN® age group triathletes from 446 events at 65 different locations between 2002 and 2022 were analyzed. Figure 1 shows the histograms and overlapping normal density distributions of the split and full race finish times for each sex, where the bike and run times exhibit a small positive skewness.

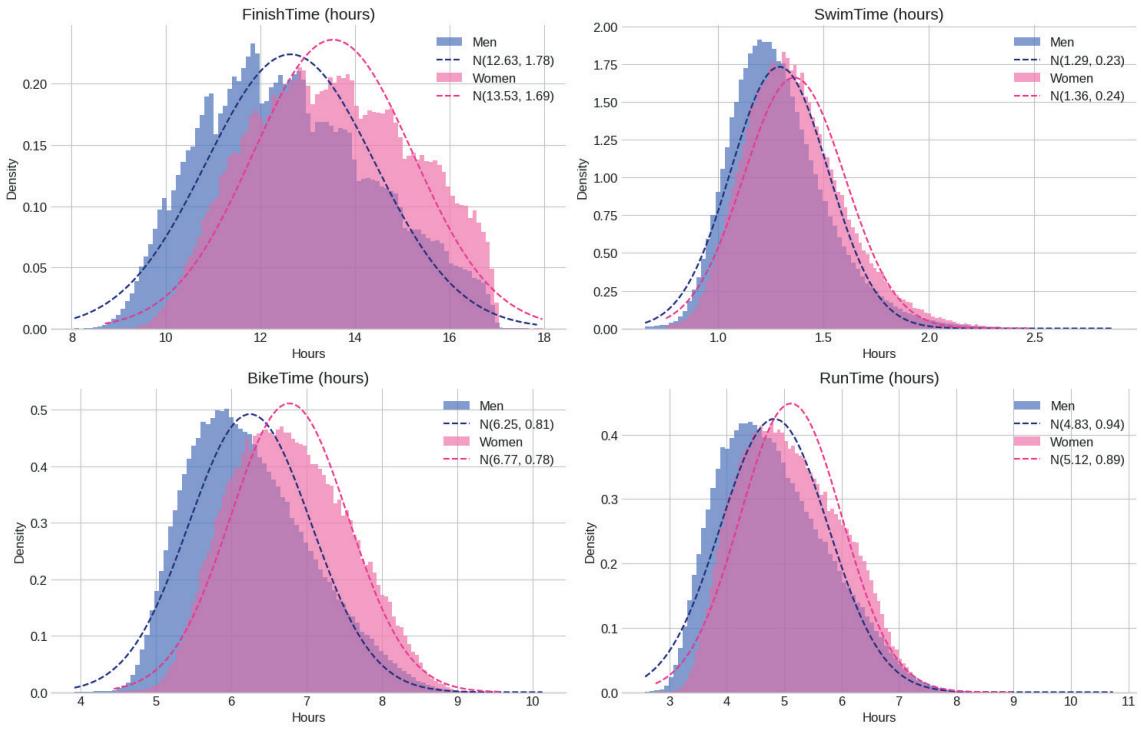

Figure 1. Histograms of the split and overall race times for each sex for IRONMAN® age group triathletes competing between 2002 and 2022

Swimming

Figure 2 shows the IRONMAN® races with the fastest swimming courses in the form of strip plots. The fastest swim times were achieved in IRONMAN® New York, ahead of IRONMAN® Switzerland in Thun and IRONMAN® Chattanooga for both men (Table 1) and women (Table 2). For the swim times, there are statistically significant differences among the locations ($p < 0.05$) for 'event location' and 'sex' and for the interaction 'event location' × 'sex'.

Cycling

Figure 3 shows the IRONMAN® races with the fastest cycling courses. The fastest cycling times were achieved in IRONMAN® Barcelona, ahead of IRONMAN® Copenhagen and IRONMAN® Vitoria-Gasteiz. Regarding the sexes, the fastest cycling splits were in IRONMAN® Barcelona, IRONMAN® Copenhagen and IRONMAN® Tallinn for men (Table 3) and IRONMAN® Barcelona, IRONMAN® Copenhagen and IRONMAN® Vitoria-Gasteiz for women (Table 4). For the cycling times, there are statistically significant differences among the locations ($p < 0.05$) for 'event location' and 'sex' and for the interaction 'event location' × 'sex'.

Running

Figure 4 shows the IRONMAN® races with the fastest running courses. The fastest running times were achieved in IRONMAN® Hawaii, ahead of IRONMAN® Vitoria-Gasteiz and IRONMAN® Tallinn. Men achieved the fastest running split in the races in the mentioned order (Table 5), whereas women were the fastest in running in IRONMAN® Gdynia, IRONMAN® Haugesund Norway and IRONMAN® Hawaii (Table 6). For the running times, there are statistically significant differences among the locations [(p-values PR (>F) are zero or very small ($p < 0.05$)] for 'event location' and 'sex' and for the interaction 'event location' × 'sex'.

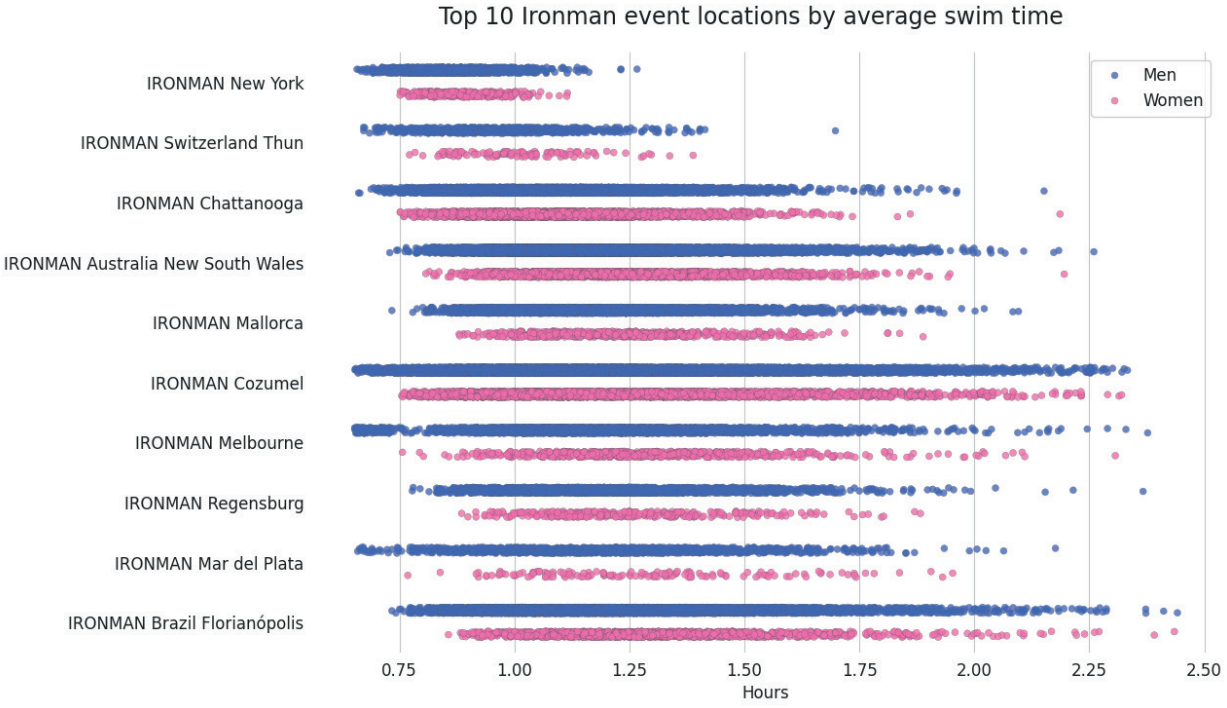

Figure 2. IRONMAN® races sorted by the 10 fastest swimming courses

Table 1. IRONMAN® races sorted by the fastest swim split times (h:min:s) for men

Race	n	Mean	SD	Fastest	Slowest
IRONMAN® New York	1627	00:51:47	00:04:56	00:39:28	01:16:00
IRONMAN® Switzerland Thun	766	00:57:46	00:08:30	00:40:19	01:41:53
IRONMAN® Chattanooga	7463	01:04:31	00:09:55	00:39:40	02:09:06

IRONMAN® Australia New South Wales	11439	01:10:19	00:10:57	00:43:44	02:15:36
IRONMAN® Mallorca	5570	01:10:48	00:10:24	00:44:01	02:05:46
IRONMAN® Cozumel	13844	01:11:18	00:15:42	00:39:11	02:19:59
IRONMAN® Melbourne	3970	01:11:35	00:13:26	00:39:09	02:22:37
IRONMAN® Mar del Plata	1352	01:12:06	00:14:13	00:39:33	02:10:35
IRONMAN® Regensburg	2505	01:12:08	00:11:34	00:46:41	02:22:01
IRONMAN® Brazil Florianópolis	12466	01:12:21	00:12:28	00:44:01	02:26:30

Table 2. IRONMAN® races sorted by the fastest swim split times (h:min:s) for women

Race	n	Mean	SD	Fastest	Slowest
IRONMAN® New York	328	00:53:29	00:04:17	00:45:05	01:06:55
IRONMAN® Switzerland Thun	119	01:00:38	00:07:22	00:46:19	01:23:19
IRONMAN® Chattanooga	3336	01:06:50	00:09:34	00:45:06	02:11:11
IRONMAN® Mallorca	695	01:14:00	00:10:18	00:52:48	01:53:19
IRONMAN® Australia New South Wales	2234	01:14:13	00:10:54	00:48:27	02:11:44
IRONMAN® Cozumel	4089	01:14:33	00:16:00	00:45:18	02:19:13
IRONMAN® Regensburg	321	01:15:21	00:11:30	00:53:07	01:52:58
IRONMAN® Melbourne	699	01:17:21	00:13:10	00:45:24	02:18:24
IRONMAN® Mar del Plata	144	01:17:22	00:14:51	00:46:06	01:57:11
IRONMAN® Brazil Florianópolis	1555	01:18:45	00:13:43	00:51:24	02:26:06

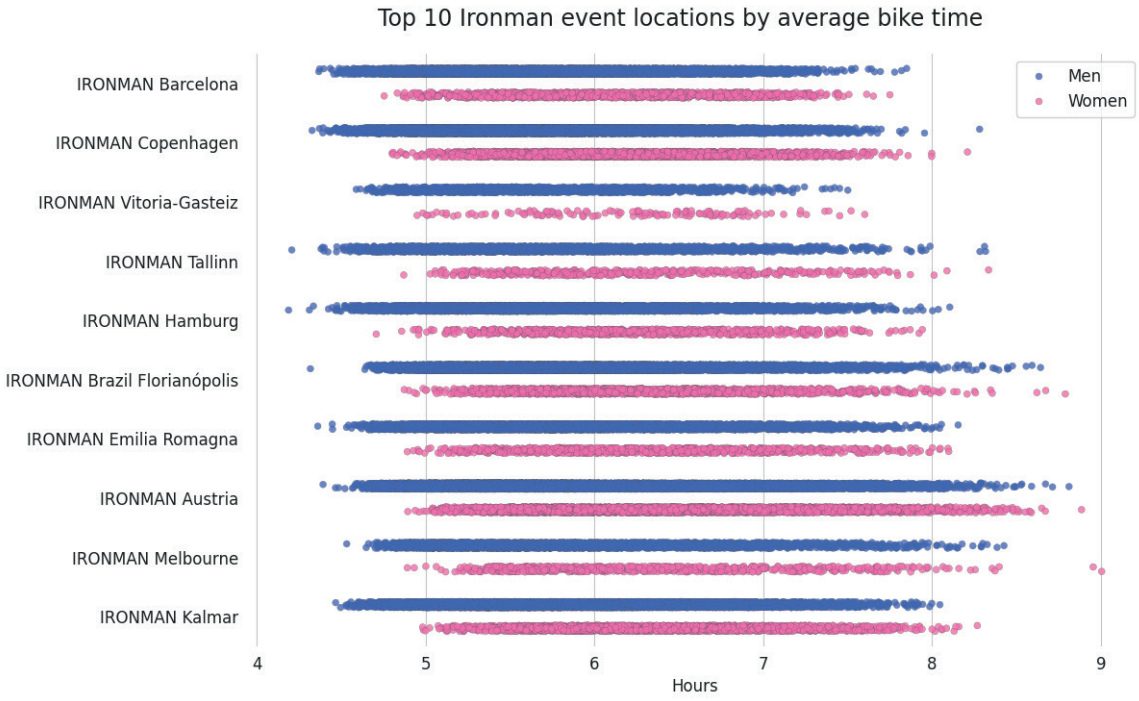

Figure 3. IRONMAN® races sorted by the 10 fastest cycling courses

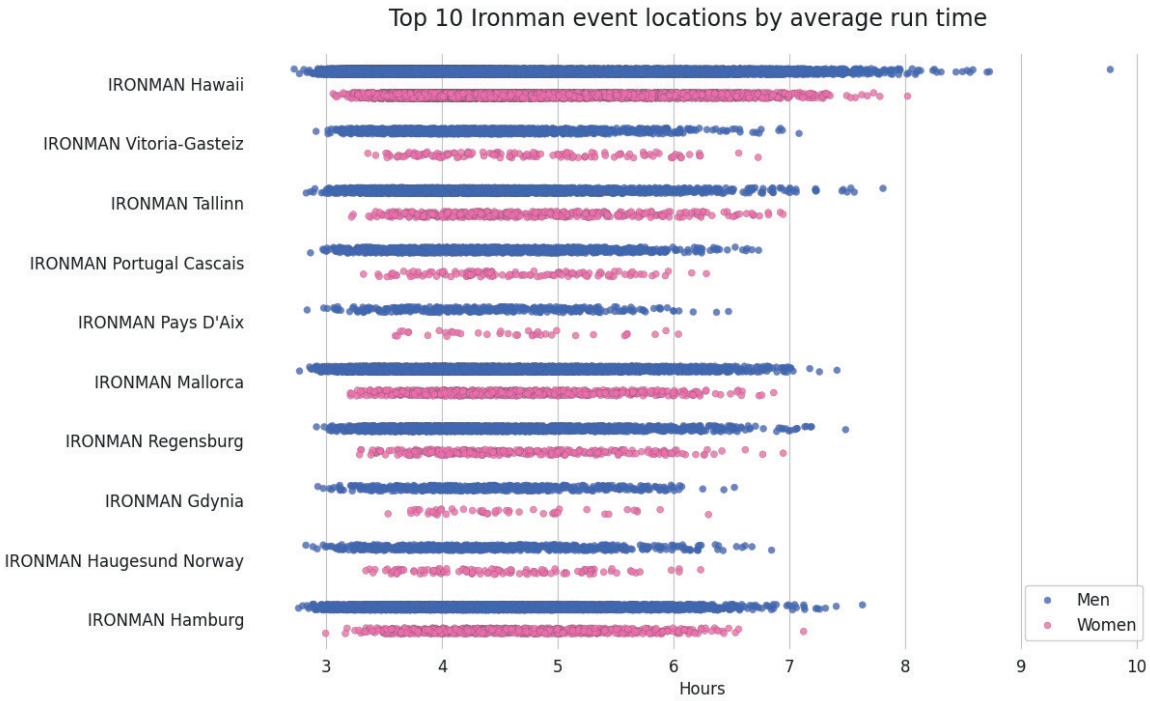

Figure 4. IRONMAN® races sorted by the 10 fastest running courses

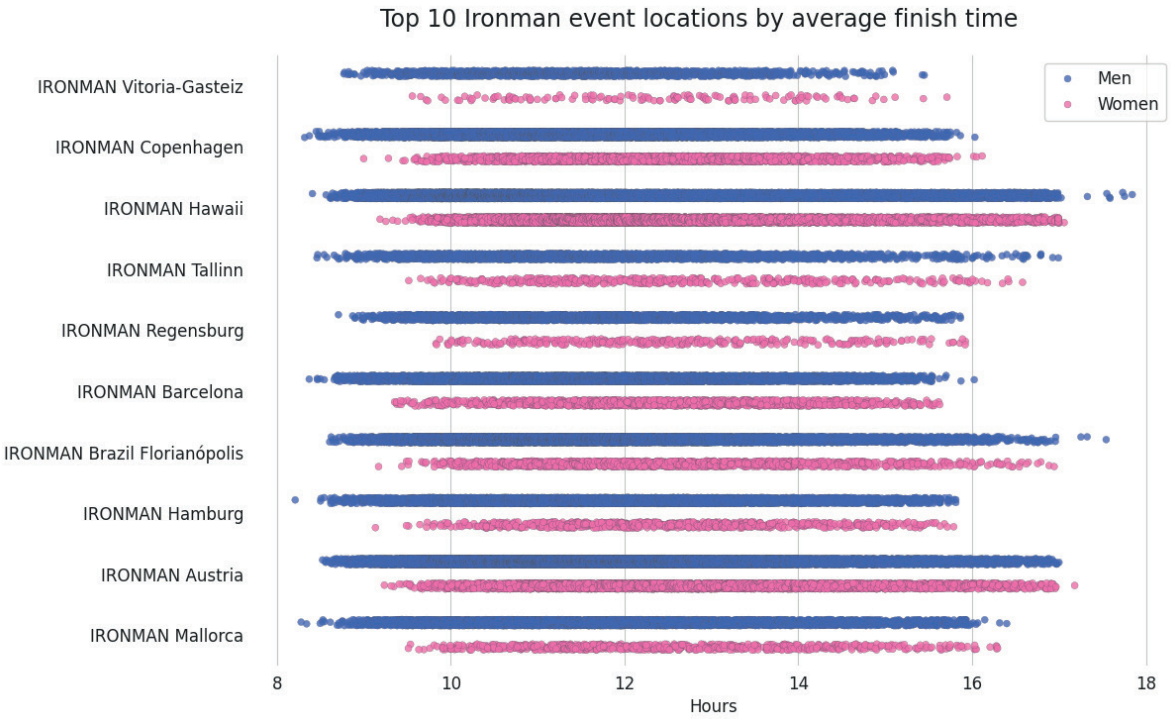

Figure 5. IRONMAN® races sorted by the 10 fastest overall race times

Table 3. IRONMAN® races sorted by the fastest cycling split times (h:min:s) for men

Race	n	Mean	SD	Fastest	Slowest
IRONMAN® Barcelona	9819	05:37:58	00:34:15	04:21:57	07:50:57
IRONMAN® Copenhagen	14252	05:38:43	00:33:08	04:19:33	08:16:54
IRONMAN® Tallinn	2895	05:41:52	00:40:37	04:12:20	08:19:01
IRONMAN® Vitoria-Gasteiz	1435	05:43:03	00:33:04	04:35:14	07:30:02
IRONMAN® Hamburg	5894	05:46:39	00:37:16	04:11:12	08:06:17
IRONMAN® Austria	29032	05:48:52	00:38:47	04:23:27	08:48:41
IRONMAN® Brazil Florianópolis	12466	05:49:29	00:36:50	04:18:57	08:38:34
IRONMAN® Melbourne	3970	05:49:38	00:42:54	04:31:52	08:25:34
IRONMAN® Kalmar	12289	05:49:48	00:35:40	04:27:57	08:02:47
IRONMAN® Emilia Romagna	7195	05:49:56	00:38:16	04:21:34	08:09:16

Table 4. IRONMAN® races sorted by the fastest cycling split times (h:min:s) for women

Race	n	Mean	SD	Fastest	Slowest
IRONMAN® Barcelona	1322	06:08:18	00:35:14	04:45:11	07:45:00
IRONMAN® Copenhagen	2499	06:08:28	00:34:23	04:48:01	08:12:36
IRONMAN® Vitoria-Gasteiz	137	06:12:13	00:37:29	04:56:54	07:36:04
IRONMAN® Tallinn	438	06:13:23	00:42:05	04:52:09	08:20:06
IRONMAN® Hamburg	774	06:15:11	00:37:01	04:42:22	07:56:32
IRONMAN® Brazil Florianópolis	1555	06:17:41	00:39:28	04:52:19	08:47:22
IRONMAN® Emilia Romagna	883	06:20:37	00:41:02	04:53:25	08:05:55
IRONMAN® Melbourne	699	06:20:41	00:44:39	04:53:25	09:00:18
IRONMAN® Kalmar	2362	06:21:22	00:36:57	04:58:51	08:16:05
IRONMAN® Austria	4229	06:28:07	00:43:47	04:53:35	08:53:08

Table 5. IRONMAN® races sorted by the fastest running split times (h:min:s) for men

Race	n	Mean	SD	Fastest	Slowest
IRONMAN® Hawaii	23760	04:17:21	00:57:52	02:43:28	09:46:10
IRONMAN® Vitoria-Gasteiz	1435	04:21:00	00:43:49	02:54:48	07:04:58
IRONMAN® Tallinn	2895	04:21:50	00:47:02	02:49:41	07:48:28
IRONMAN® Portugal Cascais	1266	04:23:47	00:45:08	02:51:53	06:44:02
IRONMAN® Pays D'Aix	345	04:23:52	00:43:29	02:50:10	06:28:27
IRONMAN® Regensburg	2505	04:23:55	00:46:25	02:55:00	07:29:06
IRONMAN® Mallorca	5570	04:24:14	00:47:30	02:46:14	07:24:38
IRONMAN® Hamburg	5894	04:24:24	00:47:08	02:45:42	07:37:49
IRONMAN® Norway Haugesund	712	04:25:10	00:47:36	02:49:33	06:50:44
IRONMAN® Gdynia	550	04:25:33	00:44:11	02:55:41	06:31:29

Table 6. IRONMAN® races sorted by the fastest running split times (h:min:s) for women

Race	n	Mean	SD	Fastest	Slowest
IRONMAN® Gdynia	51	04:30:43	00:39:50	03:32:06	06:18:04
IRONMAN® Norway Haugesund	113	04:31:16	00:41:21	03:20:34	06:14:01
IRONMAN® Hawaii	8426	04:32:37	00:50:27	03:03:38	08:01:14
IRONMAN® Mallorca	695	04:34:35	00:45:00	03:12:34	06:51:50
IRONMAN® Pays D'Aix	38	04:35:42	00:41:32	03:35:48	06:02:30
IRONMAN® Portugal Cascais	124	04:36:50	00:40:59	03:19:21	06:16:59
IRONMAN® Regensburg	321	04:37:23	00:44:59	03:17:18	06:56:45
IRONMAN® Hamburg	774	04:38:18	00:43:36	02:59:45	07:07:19
IRONMAN® Vitoria-Gasteiz	137	04:39:57	00:48:32	03:21:37	06:43:47
IRONMAN® Tallinn	438	04:41:28	00:48:41	03:13:11	06:56:41

Table 7. IRONMAN® races sorted by the fastest overall race times (h:min:s) for men

Race	n	Mean	SD	Fastest	Slowest
IRONMAN® Hawaii	23760	11:28:22	01:52:13	08:24:36	17:50:33
IRONMAN® Vitoria-Gasteiz	1435	11:30:45	01:19:33	08:46:18	15:26:59
IRONMAN® Copenhagen	14252	11:33:23	01:20:43	08:19:14	16:01:56
IRONMAN® Tallinn	2895	11:36:38	01:33:39	08:27:45	16:59:37
IRONMAN® Regensburg	2505	11:40:03	01:26:59	08:42:34	15:52:01
IRONMAN® Barcelona	9819	11:40:36	01:24:32	08:22:24	16:01:29
IRONMAN® Brazil Florianópolis	12466	11:42:48	01:29:36	08:36:29	17:32:34
IRONMAN® Austria	29032	11:44:39	01:31:56	08:31:37	16:59:59
IRONMAN® Hamburg	5894	11:45:32	01:29:25	08:12:43	15:48:47
IRONMAN® Mallorca	5570	11:49:27	01:33:25	08:16:48	16:23:56

Table 8. IRONMAN® races sorted by the fastest overall race times (h:min:s) for women

Race	n	Mean	SD	Fastest	Slowest
IRONMAN® Vitoria-Gasteiz	137	12:22:45	01:28:34	09:33:34	15:42:38
IRONMAN® Hawaii	8426	12:24:28	01:38:31	09:11:16	17:03:36
IRONMAN® Copenhagen	2499	12:24:57	01:20:14	09:00:00	16:06:57
IRONMAN® Regensburg	321	12:28:29	01:30:29	09:49:53	15:55:22
IRONMAN® Brazil Florianópolis	1555	12:31:25	01:31:06	09:10:17	16:56:41
IRONMAN® Barcelona	1322	12:31:53	01:22:49	09:21:19	15:37:39
IRONMAN® Hamburg	774	12:31:55	01:24:19	09:08:07	15:47:17
IRONMAN® Tallinn	438	12:32:32	01:38:13	09:31:06	16:34:51
IRONMAN® Mallorca	695	12:32:57	01:33:46	09:30:50	16:17:34
IRONMAN® Austria	4229	12:51:05	01:38:29	09:14:16	17:10:50

Table 9. The ten fastest IRONMAN® race locations by swimming time with race course characteristics

Event	Number of races	Number of records	Number of unique athlete names	Average race time (hours)	Average swim time (hours)	Average bike time (hours)	Average run time (hours)	Swim	Bike	Run	Water (°C)	Air (°C)
IRONMAN® New York	1	1955	1950	13.028	0.868	6.562	5.327	bay	flat	flat	18	21
IRONMAN® Switzerland Thun	1	885	885	11.926	0.969	6.103	4.655	lake	hilly	flat	17	20
IRONMAN® Chattanooga	6	10799	9614	13.459	1.087	6.606	5.467	river	rolling	rolling	25	24
IRONMAN® Australia New South Wales	12	13673	8458	12.580	1.183	6.358	4.849	river	rolling	flat	23	21
IRONMAN® Mallorca	5	6265	5792	11.905	1.186	6.067	4.423	ocean	hilly	flat	17	25
IRONMAN® Cozumel	13	17933	14483	13.061	1.201	6.444	5.157	ocean	flat	flat	26	26
IRONMAN® Melbourne	4	4669	3987	12.010	1.208	5.905	4.691	bay	flat	flat	17	18
IRONMAN® Regensburg	2	2826	2703	11.759	1.209	5.933	4.424	lake	rolling	flat	22	26
IRONMAN® Mar del Plata	3	1496	1376	12.158	1.210	6.282	4.452	ocean	rolling	rolling	19	20
IRONMAN® Brazil Florianópolis	10	14021	9666	11.803	1.218	5.877	4.462	ocean	flat	flat	20	21

Table 10. The ten fastest IRONMAN® race locations by cycling time with race course characteristics

Event	Number of races	Number of records	Number of unique athlete names	Average race time (hours)	Average swim time (hours)	Average bike time (hours)	Average run time (hours)	Swim	Bike	Run	Water (°C)	Air (°C)
IRONMAN® Barcelona	6	11141	10135	11.778	1.272	5.693	4.587	lake	hilly	rolling	23	21
IRONMAN® Copenhagen	8	16751	13354	11.685	1.270	5.719	4.468	bay	rolling	flat	18	21
IRONMAN® Vitoria-Gasteiz	1	1572	1568	11.588	1.251	5.760	4.378	lake	rolling	flat	21	22
IRONMAN® Tallinn	4	3333	3009	11.733	1.343	5.767	4.407	lake	rolling	flat	18	17

IRONMAN® Hamburg	4	6668	6263	11.849	1.305	5.833	4.434	lake	flat	rolling	21	23
IRONMAN® Brazil Florianópolis	10	14021	9666	11.803	1.218	5.877	4.462	ocean	flat	flat	20	21
IRONMAN® Emilia Romagna	4	8078	7272	11.959	1.221	5.888	4.563	ocean	flat	flat	22	25
IRONMAN® Austria	16	33261	24797	11.885	1.268	5.898	4.497	lake	rolling	flat	23	27
IRONMAN® Melbourne	4	4669	3987	12.010	1.208	5.905	4.691	bay	flat	flat	17	18
IRONMAN® Kalmar	8	14651	9836	12.082	1.360	5.915	4.602	ocean	flat	flat	20	22

Table 11. The ten fastest IRONMAN® race locations by running time with race course characteristics

Event	Number of races	Number of records	Number of unique athlete names	Average race time (hours)	Average swim time (hours)	Average bike time (hours)	Average run time (hours)	Swim	Bike	Run	Water (°C)	Air (°C)
IRONMAN® Hawaii	18	32186	21094	11.718	1.238	5.942	4.356	ocean	rolling	rolling	24	27
IRONMAN® Vitoria-Gasteiz	1	1572	1568	11.588	1.251	5.760	4.378	lake	rolling	flat	21	22
IRONMAN® Tallinn	4	3333	3009	11.733	1.343	5.767	4.407	lake	rolling	flat	18	17
IRONMAN® Portugal Cascais	1	1390	1384	12.309	1.285	6.331	4.416	bay	hilly	rolling	17	18
IRONMAN® Pays D'Aix	1	383	383	12.338	1.237	6.432	4.418	lake	hilly	rolling	18	20
IRONMAN® Mallorca	5	6265	5792	11.905	1.186	6.067	4.423	ocean	hilly	flat	17	25
IRONMAN® Regensburg	2	2826	2703	11.759	1.209	5.933	4.424	lake	rolling	flat	22	26
IRONMAN® Gdynia	1	601	599	12.288	1.367	6.221	4.433	ocean	hilly	hilly	17	16
IRONMAN® Hamburg	4	6668	6263	11.849	1.305	5.833	4.434	lake	flat	rolling	21	23
IRONMAN® Norway Haugesund	2	825	779	12.373	1.266	6.443	4.434	lake	rolling	flat	17	18

Table 12. The ten fastest IRONMAN® race locations by overall race times with race course characteristics

Event	Number of races	Number of records	Number of unique athlete names	Average race time (hours)	Average swim time (hours)	Average bike time (hours)	Average run time (hours)	Swim	Bike	Run	Water (°C)	Air (°C)
IRONMAN® Vitoria-Gasteiz	1	1572	1568	11.588	1.251	5.760	4.378	lake	rolling	flat	21	22
IRONMAN® Copenhagen	8	16751	13354	11.685	1.270	5.719	4.468	bay	rolling	flat	18	21
IRONMAN® Hawaii	18	32186	21094	11.718	1.238	5.942	4.356	ocean	rolling	rolling	24	27
IRONMAN® Tallinn	4	3333	3009	11.733	1.343	5.767	4.407	lake	rolling	flat	18	17
IRONMAN® Regensburg	2	2826	2703	11.759	1.209	5.933	4.424	lake	rolling	flat	22	26
IRONMAN® Barcelona	6	11141	10135	11.778	1.272	5.693	4.587	lake	hilly	rolling	23	21
IRONMAN® Brazil Florianópolis	10	14021	9666	11.803	1.218	5.877	4.462	ocean	flat	flat	20	21
IRONMAN® Hamburg	4	6668	6263	11.849	1.305	5.833	4.434	lake	flat	rolling	21	23
IRONMAN® Austria	16	33261	24797	11.885	1.268	5.898	4.497	lake	rolling	flat	23	27
IRONMAN® Mallorca	5	6265	5792	11.905	1.186	6.067	4.423	ocean	hilly	flat	17	25

Overall race performance

Figure 5 shows the IRONMAN® races with the fastest overall race times. The fastest overall race times were achieved in IRONMAN® Vitoria-Gasteiz, IRONMAN® Copenhagen, and IRONMAN® Hawaii. Men achieved their fastest overall race times in IRONMAN® Hawaii, IRONMAN® Vitoria-Gasteiz and IRONMAN® Copenhagen (Table 7). For women, the fastest overall race times were achieved in IRONMAN® Vitoria-Gasteiz, IRONMAN® Hawaii and IRONMAN® Copenhagen (Table 8). For the overall race times, there are statistically significant differences among the locations [(p-values PR (>F) are zero or very small ($p < 0.05$)] for 'event location' and 'sex' and for the interaction 'event location' × 'sex'.

Environmental characteristics

Regarding swimming, the average water temperature was 20.4 ± 3.2 °C and most swimming courses were held in an ocean (4/10) (Table 9). For cycling, the average air temperature was 20.5 ± 2.0°C and most cycling courses were described as flat (6/10) (Table 10). Considering running, the average air temperature was 19.2 ± 2.4 °C. Most running courses were described as flat (5/10) (Table 11). For overall race times, the average water temperatures were 20.7 ± 2.8 °C and the average air temperatures 23.0 ± 3.0 °C (Table 12). Most swimming courses were in a lake (7/10), most cycling courses were rolling (6/10) and most running courses were flat (7/10).

Discussion

The purpose of this study was to find the fastest event locations for IRONMAN® age group triathletes competing from 2002 to 2022. We found sex differences regarding the fastest overall race times, the fastest cycling and running courses, but not regarding the swimming courses. From the main results, we verified an influence of the event location and the sex on the race time. Previous studies discussed the influence of sex on endurance performance [7, 16, 21].

Few studies were conducted to understand the characteristics of event location in non-professional triathletes, which limits the comparison of the results. A common point among these three disciplines is the country where the competition occurs. Historically, the USA was the first country to host a triathlon competition. Trends in participation and performance also show that amateur competitors from the USA present the highest participation rates and performance levels compared to those from other countries [3]. In addition, the USA also concentrates on the higher number of competitions, which can be associated with the present results [9]. Additionally, the USA is one of the countries that have higher development in the disciplines of triathlon [26]. Nonetheless, the geographical characteristics of the place of competition were not explored previously. The lack of information about the role of physical characteristics in triathletes' performance is related to the higher interest in understanding individual characteristics (e.g., training experience, age, sex, nutrition, and genetic factors) [21, 29, 38] that contribute to the higher achievement of the sports context. Previous publications, on the other hand, highlighted the complexity of the endurance activities as well as the importance of considering the athletes' behavior as an outcome of the environmental responses [34].

We found that IRONMAN® Hawaii was the fastest race course for men and the second fastest course for women. The most likely explanation is that IRONMAN® Hawaii is the IRONMAN® World Championship and only the best female and male IRONMAN® age group triathletes can compete there [33]. When all races were considered, the fastest marathons were achieved in IRONMAN® Hawaii. Separated by sex, the fastest marathon was in IRONMAN® Hawaii for men and in third place for women. A potential explanation for this finding could be the fact that the personal best marathon time is for both male [35] and female [36] age group IRONMAN® triathletes an important predictor for a fast IRONMAN® race time. Another explanation could be that IRONMAN® Hawaii has a flat and fast running course [41].

The ambient temperatures for water and air were at ~20-23 °C. Environmental conditions (e.g., hot, cold, humidity, wind, and altitude) have been considered a primary regulator of human performance and exercise [13, 40]. For instance, it was observed in age group marathoners competing in the Berlin Marathon that higher daily maximum temperatures and precipitation levels impaired performance [17]. Furthermore, with regard to the swimming discipline, it was previously suggested that water temperature, tides, currents, and waves influenced performance [1]. In cycling, it has been found that performance (power output) would decrease as a result of heat stress during self-paced exercise [42]. These observations highlighted the potential role of the environmental conditions in the various event locations and the effects of the environmental conditions on the athletes' physiological self-regulation [6].

We found that most swimming courses were in a lake, most cycling courses were rolling and most running courses were flat. While we have a lot of knowledge

regarding the influence of the weather [23, 37], little is known about the influence of race course characteristics on endurance performance. In running, studies tried to investigate the differences between different running surfaces [8, 10]. A recent study investigating 72-hour ultra-marathoners found, however, that the fastest races are held on a track, followed by road running, and then trail running. Furthermore, flat race courses were leading to faster running speeds than hilly race courses [18]. More research is needed to investigate the importance of specific race course characteristics in endurance performance.

The present study does have limitations. Firstly, despite our intention to access the event location, no information regarding the race course characteristics was considered during the analysis. This is an important aspect to consider since it impairs the comprehension regarding the environmental factors that affect performance. Secondly, performance and environmental characteristics are dynamic phenotypes. In this sense, the prediction power of our analysis is limited. Thirdly, no individual characteristics or a specific analysis by sex were considered. Despite secondary data that has been used over the last years to understand the runners' profile and pattern of participation and performance, no training (e.g., experience, training load) or morphological characteristics (e.g., body mass, body height) are available. Based on the increase in the use of this information to build the evidence about the influence of environmental conditions, event organizations and sports associations should consider obtaining additional information from competitors to be able to advance the comprehension of these groups and specificities. Our study, however, does not provide very detailed information about the physical (e.g., elevation changes, hills, slopes) or weather characteristics (e.g., windy velocity, humidity), or natural elements (open water swims in lakes, oceans, or rivers), that could provide a better comprehension regarding the variables associated with these results [7, 20, 40]. Future studies might investigate more deeply the role of the environmental characteristics of non-professional IRONMAN® triathlete results. From another perspective, the present study contributes to understanding event location that potentially influences performance in non-elite groups. Despite the fact that some of these participants use triathlon as a leisure sport, they devote time and financial resources to it, thus, indicating the importance of considering the best options (in terms of the possibility of performing well) of competitions.

Conclusions

Despite differences regarding the event locations, the fastest race courses were identified in the USA and Spain. The fastest times were achieved in different event locations for the three different disciplines. Considering the increasing popularity of triathlon for age group athletes reflected in the relevant literature, our findings would have practical applications in the context of the optimal event location selection.

Conflict of Interest

The authors have no conflicts of interest to report.

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