The aspects of sex, age and nationality in winter swimming performance

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Abstract. – **OBJECTIVE:** Winter swimming is a new sport discipline. Very little is known, however, about the sex differences, origin, participation and performance of the world's best winter swimmers. Therefore, the study aimed to investigate sex differences in performance and age. Furthermore, it should be determined which country has the fastest swimmers, the highest numbers of participants and the most successful age group athletes in winter swimming.

SUBJECTS AND METHODS: A total of 6,477 results from the 25 m events of the IWSA (International Winter Swimming Association) World Cups from 2016-2020 was collected from the official website of IWSA. Data were analyzed using a generalized linear model (GLM) with a gamma probability distribution and identity link function. The 25 m events were carried out in head-up breaststroke style, freestyle and butterfly. The nationalities were grouped into six groups, the five nationalities with the highest number of participants in the 25 m competitions and one group with the other nationalities. The mean time of 25 m races by sex and country of the total sample was compared. For the top 10 comparisons, the best ten athletes from the six groups were selected. The mean time of each top 10 groups was compared by sex and nationality.

RESULTS: Men were faster than women for all categories. Swimmers in age group 15-29 years were the fastest, where females were the fastest in age group 15-19 years and males in age group 20-29 years. Women from both Russia and Estonia and men from both Russia and China were the fastest. Both Russian and Chinese males were the fastest in all water categories in the top 10 section in the 25 m events.

CONCLUSIONS: In summary, males were faster than females in the IWSA World Cups between 2016 and 2020. The age group of 15-29 years old athletes was the most successful while females had their age of peak performance earlier than males. Russian and Estonian males and Russian females were the overall fastest in the 25 m events in all water categories. Future studies should investigate the optimal anthropometric characteristics of male and female winter swimming sprint athletes and whether there are distinct areas in Russia, Estonia and China, where many international winter swimming athletes originate.

Key Words:
Age group athletes, Nationality, Participation, Performance, Water sport, Winter swimming.

Introduction

Winter swimming is a young sports discipline that has gained more and more attention over the last few years[1]. Although it has a long tradition in Russia, Estonia, Finland, Latvia, Slovenia and Sweden, it recently became a competitive sports discipline with international events[2].

Since 2015, the IWSA (International Winter Swimming Association) has hosted the IWSA World Cup Series to provide a safe international event with clear rules and classifications for athletes who want to reach a world-class level[3]. As

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the IWSA and the IISA (International Ice Swimming Association) monitor their records, they intend to introduce winter swimming as a discipline for the future Winter Olympic Games. The IISA focuses more on the extreme Ice Mile and 1 km ice swimming event with temperatures of +5°C or less[4]. In the IWSA World Cups, the emphasis lies on shorter distances (i.e., 25 m, 50 m, 100 m and 200 m) and different swimming strokes (i.e., freestyle, head-up breaststroke, butterfly). The water temperature ranges from -2°C to +9°C is more comprehensive than for the IISA events[3].

Open water swimming, in general, is a subject of scientific research because of its increasing popularity[5] and the interesting reactions of the human body to extreme conditions in open water[6]. One example is the impaired cognitive function of open water swimmers under cold conditions, which could be ameliorated through cold acclimation[7]. Other aspects of the investigations that were already conducted are, among others, the nationality[5,8,9] and the different age groups of the athletes concerning their performance and participation[9]. The results set the cornerstone for the evolution of open water swimming. A more detailed understanding of preparation and safety measures in open water resulted in higher performances[8,10].

Open water swimming is getting more and more extreme in terms of longer distances and decreasing water temperatures[11]. For example, Sarah Thomas swam in 2017 the 168.3 km long Gardiner Island loop from Rouses point (New York/Vermont, USA) without a break or assistance as the longest open water solo swim to date[12]. The 'Extreme Ice Mile,' a category in the Ice mile series events of the IISA, is recognized when the swim is completed in water temperatures of +2 °C or lower[13]. Further research is needed to improve safety, preparation measures and performance for such extreme conditions.

Sex differences in sports performance of various sports disciplines have been of significant scientific interest over the last years[14,15,16]. It has been established that males outperform women[16], although the magnitude of the sex gap depends on different aspects such as sports discipline[16,17], distance[18], age[17,19,20] and performance level[15-17]. The sex gap of performance was reported to be smaller in swimming than in running and cycling for triathlon events[21]. In open water swimming, women could narrow the sex gap over time[17,22] and even outperform men, especially in cold conditions and over distances of more than 30 km[17]. However, in pool swimming and over sprint distances, males are known to be faster than females[23-25]. The sex difference in performance in relation to age was the smallest in very young swimmers (under ten years of age) and very old swimmers (from 75 to 80 years of age)[17]. In breaststroke swimming, there were more significant sex-related differences in performance at national level compared to international level[26].

It is known that countries or regions that have a preference for certain sports traditions in conjunction with a large population from which to draw talent produce some of the most successful athletes at competitive international events[27,28.] Moreover, recent research showed that environmental[29,30], genetic[29-31] and socio-cultural factors[28,30] contributed to athletes' success from these distinct areas. The most famous examples are the Jamaican sprinters (100 m, 200 m, 400 m)[29] and the East African middle distance and marathon runners[32,33], who dominated their disciplines for decades. The large majority of Jamaican sprinters came from the Surrey County, the easternmost region of the island[29]. Demographic studies of international Kenyan middle-distance runners showed that most grew up in the Rift Valley region. Moreover, most of them had a social background of the Kalenjin ethnic group and the daily habit of running long distances to school[32]. Analog to the demographic pattern of Kenyan professional runners, most national marathon runners from Ethiopia originated from the Arsi and Shewa regions. They belonged to the Cushitic speaking ethnical groups and regularly ran greater distances to school or general travelling[30]. Furthermore, Russia was identified as the dominating nation with the fastest athletes in ultra-endurance sports events such as the 'Comrades Marathon' in 1994-2017 and in 100-km ultra-marathons worldwide in the years from 1959-2016[34]. In winter sports, the Norwegians, with a small population of just 5,4 million people, are the Olympic Winter Games medal table leaders[35,36]. Furthermore, for the two popular long-distance cross-country skiing events, the 'Engadin Ski Marathon' (1998-2016) and 'Vasaloppet' (1922-2017), Russia was reported to be the fastest nation[34].

The FINA (Fédération Internationale de Natation) is an international federation that administers competitive open water swimming races for distances of 5 km, 10 km and 25 km where athletes compete head-to-head[37]. An investigation of the races covering these distances from 2000 to 2016 showed that Europeans were the most numerous for races held in Europe, and for races held in the

USA, Americans were predominant5. It is known that in pool swimming, America and Australia are the dominating nations[38]. Still, interestingly, no dominating nation could be identified for the overall FINA long-distance open water races held from 2000 till 2016[5]. In the 5 km events, the Dutch and Spanish were among the fastest. For the 10 km races, the Malaysians and Danish and in the 25 km, the Czech, German, Spanish and Italian swimmers were the fastest[5]. Men were faster than women in these events regardless of the distance5. Italy placed most starters before the USA and Germany in the 3000 m FINA World Master Championships between 1992 and 2019. The Italians were also the overall fastest athletes in these events. In addition to that, the analysis showed that the age group of 35 to 39 years old individuals was the overall fastest[9].

The 'Triple Crown of Open Water Swimming' consists of the 'English Channel Swim' (33.7 km), the 'Catalina Channel Swim' (33 km) and the 'Manhattan Island Marathon Swim' (45.8 km)[39]. Unlike the FINA races, the Triple Crown events are solo events (no drafting) with fewer master swimmers, especially in the 'Catalina Channel Swim' and the 'Manhattan Island Marathon Swim'[8]. An analysis of the finishers of all these events that took place between 1875 and 2017 showed a higher participation of swimmers from the USA in events held in the USA ('Catalina Channel Swim' and the 'Manhattan Island Marathon Swim') and of British swimmers in the 'English Channel Swim'. Furthermore, the Australians were the fastest of all swimmers, followed by the Americans, the British and the Canadians, respectively[8]. Regarding the sex difference in these events, it was shown that women were faster than men[17].

The previously mentioned studies significantly impacted our understanding in sex differences, participation, and performance trends in open water swimming for different distances and skill levels. Winter or ice swimming is a young sports discipline in the field of open water swimming[2]. To date, no studies have been conducted that gave insights into the sex differences, participation and performance trends of international winter swimming events. Furthermore, nothing is known about the age of the fastest winter swimmers.

Therefore, this study aimed to investigate sex differences in performance, age and participation in the IWSA World Cups since their official invention in 2015. Furthermore, another aspect was determining the nationality with the highest numbers of participants and the fastest athletes. Lastly, it was aimed to identify the most successful age group of these events. Based on the before-mentioned studies in open water swimming, the first hypothesis was that male athletes were faster than females. Secondly, a high percentage of domestic swimmers from the hosting nation, which are also among the fastest in these competitions, was suspected. Furthermore, it was expected that swimmers of the age of 30-39 years would be the fastest and that there is no overall dominating nation.

Subjects and Methods

Ethical Approval

The study was conducted according to the guidelines of the Declaration of Helsinki. 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 participant as the study involved the analysis of publicly available data (EKSG 01-06-2010).

Data

The data set of this study was collected from the official IWSA website[3]. The published results of the official Winter Swimming World Cups contained the full name of the swimmer, sex, age group, nationality, distance, type of stroke, and race time. All results have been included from season 2016/2017 to season 2019/2020. Excluded was 'The 2nd Open Winter Swimming Championship of Karelia in 2020' because the results were not published and the first World Cup in 2015/2016, where the race time was not mentioned (Table I).

The rules of the IWSA World Cup comprise the defined water categories, age groups and swimming styles. The water categories are divided into category A (-2°C to +2°C), B (+2.1°C to +5°C) and C (+ 5.1°C to +9°C). The age groups are divided into group A1 (until 15 years), group A2 (15-19 years), group B (20-29 years) and group C (30-39 years). From age group C on, the groups are divided into five-year age groups (D, E, F, G, H, I, J1) until group J2 (80 years and older).

For the 25 m distance, the races were held in head-up breaststroke style, freestyle and butterfly. The head-up breaststroke style is a variant of the common breaststroke, where it is not permitted to submerge the crown of the head except for the first stroke in the first 5 m of the race. In the freestyle

Table I. Data included in the present study.

Season	Event	City	Data Included
2015/2016	7th Jelgavas Roni Cup	Jelgava	Excluded
2015/2016	4th Big Chill Swim	Windermere	Excluded
2015/2016	5th Scandinavian Winter Swimming Championships	Skelleftea	Excluded
2015/2016	7th Piritia Open	Tallinn	Excluded
2015/2016	10th Winter Swimming World Championships 2016	-	Excluded
2016/2017	8th Jelgavas Roni Cup	Jelgava	Included
2016/2017	1st Russian Pacific Winter Swimming Festival	Vladivostok	Included
2016/2017	5th Big Chill Swim	Windermere	Included
2016/2017	3rd Taierzhuang International Winter Swimming Festival	Taierzhuang	Included
2016/2017	6th Scandinavian Winter Swimming Championships	Skellefteå	Included
2016/2017	8th Pirita Open	Tallinn	Included
2017/2018	9th Jelgavas Roni Cup	Jelgava	Included
2017/2018	2nd Russian Pacific Winter Swimming Open Cup	Vladivostok	Included
2017/2018	3rd Minsk Open Cup	Minsk	Included
2017/2018	7th Scandinavian World Championships 2018	Skelleftea	Included
2017/2018	11th Winter Swimming World Championships 2018	Tallinn	Included
2018/2019	10th Jelgavas Roni Cup	Jelgava	Included
2018/2019	Bled Winter Swimming World Cup 2019	Bled	Included
2018/2019	Skellefteå Dark& Cold 2019	Skellefteå	Included
2018/2019	Petrozavodsk Russian Open Championships 2019	Petrozavodsk	Included
2019/2020	11th Jelgavas Roni Cup	Jelgava	Included
2019/2020	5th Tyumen Open Cup	Tyumen	Included
2019/2020	8th Winter Spring- Swimming (Daming Lake) International Invitational	Jinan	Included
2019/2020	12th Winter Swimming World Championships	Bled	Included
2019/2020	9th Scandinavian Winter Swimming Championship	Skellefteå	Included
2019/2020	2nd Open Winter Swimming Championships of Karelia	Karelia	Excluded

races, 'any style' could be used. In the butterfly races, a regular butterfly was the swimming style. For the head-up breaststroke, a distance of 50 m was offered additionally, and for common breaststroke, the distances of 100 m and 200 m were provided. The butterfly style was only provided for the 25 m distance, whereas additional distances of 50 m and 100 m were provided for freestyle. Endurance freestyle races were provided over 200 m, 450 m and 1000 m. The race time was reported in (00:00:00 h:min:s). With a conversion into m/s, multi-variate analysis of the speed as a common variable of dependent variables (age group, nationality, water category) could be performed[3].

Statistical Analysis

Descriptive data were presented by mean, standard deviation, maximum and minimum values. The mean values of the entire sample and the annual ten best results in each water type regardless of swimming style were selected for analysis. Data did not follow a normal distribution nor had homogeneous variances according to the Shapiro-Wilk and Levene's test, respectively. A generalized linear model (GLM) with a gamma probability distribution and identity link function was used to assess the effect of the nationality of the athlete and the advancement of the years on race time for the entire sample and for the top 10 samples by water temperature, the method of choosing the distribution of the dependent variable and the link function was the Akaike Information Criterion (AIC), using its lowest value. For this analysis, the nationalities were grouped into six groups, the five nationalities with the highest number of participants in the 25 m competitions and one group with the other nationalities. Differences found were investigated with the Post Hoc Bonferroni test. The level of significance was set at 0.05. SPSS version 26.0 (SPSS, Inc., IBM, Armonk, NY, USA) was used for all statistical analyses.

Results

To compare the performance of the swimmers by countries participating in the 25 m swim events, the five nationalities with the highest number of participants were first selected (Table II). The other countries were grouped into a single group called "Others" (Table II). First, the mean time of 25 m races by sex and country of the total sample was compared. After this initial analysis, the mean time of 25 m races by sex and country of the top 10 swimmers of each country were compared. The results section was divided into these two parts. First, data from the entire sample are presented, and, secondly, data from the top 10 comparisons are presented.

Comparison Among All Athletes from Each Country by Sex

A total of 6,477 results were recorded between 2016 and 2020 in the 25 m races. The majority of swimmers (47.6%) competed in the head-up breaststroke style (n = 3,083, 1,388 women and 1,695 men), followed by freestyle (29%, n = 1,881, 733 women and 1,148 men) and butterfly (23.4%, n = 1,513, 555 women and 958 men).

With regard to water temperature, competitions took place in three different categories. They are Ice Water (-2°C up to +2°C), Freezing Water (+2.1°C up to +5°C) and Cold Water (+5.1°C up to +9°C). The majority of swimmers (46%) competed in the Ice Water category (n = 2,980, 1,305 women and 1,675 men), followed by Freezing Water (32.4%, n = 2,099, 767 women and 1,332 men) and Cold Water (21.6%, n = 1,398, 604 women and 794 men).

The 25 m races had a total average time of 00:22.46 ± 00:07.70 (minimum 00:10.96/maximum 01:21.28) min:sec for the entire sample. The average time in each water category by sex is shown in Table III.

Regarding nationality, there were significant differences on the mean time in the 25 m events for females [x^2 (5) = 29.149, p<0.001, AIC = 18283.85] (Figure 1A) and males [x^2 (5) = 37.678, p<0.001, AIC = 23556.47] (Figure 1B).

Age groups for the entire sample also showed significant differences on the mean time in the 25 m events for females [x^2 (12) = 1291.02, p<0.001, AIC = 17260.876] (Table IV) and males [x^2 (12) = 1211.494, p<0.001, AIC = 22515.971] (Table V).

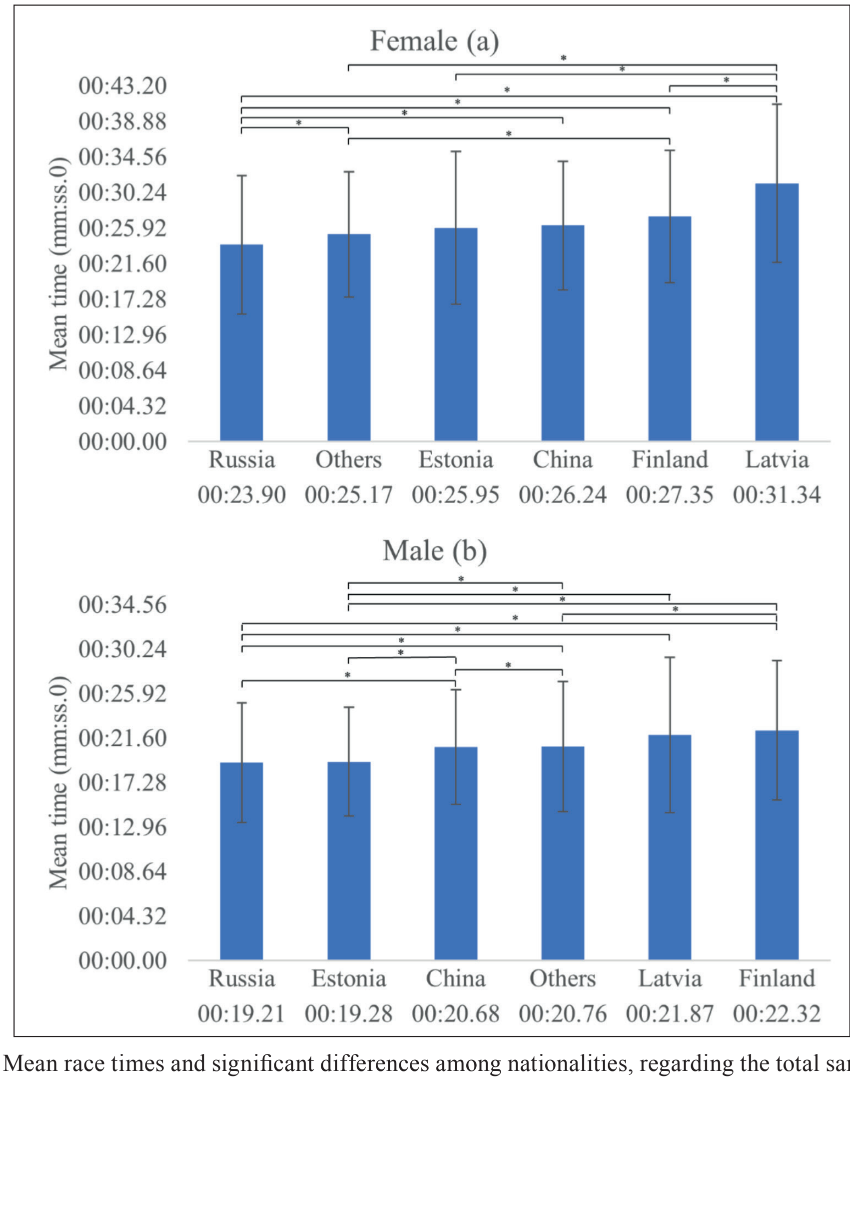

Figure 1. Mean race times and significant differences among nationalities, regarding the total sample by sex.

Table II. Sum of nationalities with the highest number of participants.

Nationality	Female (*n*)	Male (*n*)	%
Russia	859	1503	36%
Finland	386	250	10%
Estonia	227	350	9%
Latvia	185	365	8%
China	169	284	7%
Others	850	1049	29%
Total	**2676**	**3801**	**100%**

Comparison Between Top 10 Athletes from Each Country by Sex

The selection of the top 10 athletes took into account the water temperature; the ten best results per year were selected for each temperature regardless of swimming style. Between 2016 and 2020, four competitions were registered for the Ice water and Freezing water category, and three for the Cold-water category, totaling 110 results by sex. freestyle was the most present among the top 10 results with 131 observations (59.5%), followed by butterfly (70, 31.8%) and head-up breaststroke (19, 8.6%).

The female top 10 samples had an average time of 00:15.71 ± 00:01.88 (00:13.10/00:22.85) min:sec, and the male top 10 samples had an average time of 00:12.96 ± 00:01.44 (00:10.96/00:18.61) min:sec. The top 10 average times in each water category by sex are shown in Table VI.

The mean time spent by each nationality group and their differences are shown in (Figure 2A), there were significant differences [x^2 (4) = 14.415, p = 0.006, AIC = 349.26] based on the nationality of the athletes only for males (Figure 2B).

Age groups for the top 10 sample also showed no significant differences on the mean time in the 25 m events for females [x^2 (8) = 14.510, p<0.069, AIC = 436.516] (Table VII), on the other hand, the male top 10 sample showed significant differences [x^2 (6) = 62.015, p<0.001, AIC = 333.998] (Table VIII).

Discussion

This study intended to investigate sex differences, participation and performance trends of elite winter swimmers competing in 25 m races of the IWSA World Cup held between 2016 and 2020. We hypothesized that male swimmers would be faster than female swimmers. Furthermore, the fastest swimmers competing in these races would originate from the hosting countries with the most participants. Lastly, we expected that the age group of 30-39 years would be the fastest and that there would be no overall dominating nation.

The main findings were, (i) male athletes presented faster race times in 25 m than females in all water categories, (ii) considering the entire sample, the faster female and male age group was between 15 to 29 years old and females had their peak of performance earlier than males, (iii) the smallest sex gap in performance was in the

Table III. Total sample race time in each water category by sex.

	Sex Female		Male		
Category	**n (%)**	**Mean time**	**n (%)**	**Mean time**	***p*-value***
Ice water	1305 (43.8)	00:25.79 ± 00:08.45 (00:13.10/01:08.52)	1675 (56.2)	00:20.10 ± 00:06.08 (00:10.96/01:15.55)	<0.001
Freezing water	767 (36.5)	00:25.81 ± 00:08.62 (00:13.16/01:21.28)	1332 (63.5)	00:20.50 ± 00:06.58 (00:11.20/00:57.18)	<0.001
Cold water	604 (43.2)	00:25.08 ± 00:08.17 (00:14.04/01:13.68)	794 (56.8)	00:19.97 ± 00:05.94 (00:12.04/00:55.60)	<0.001

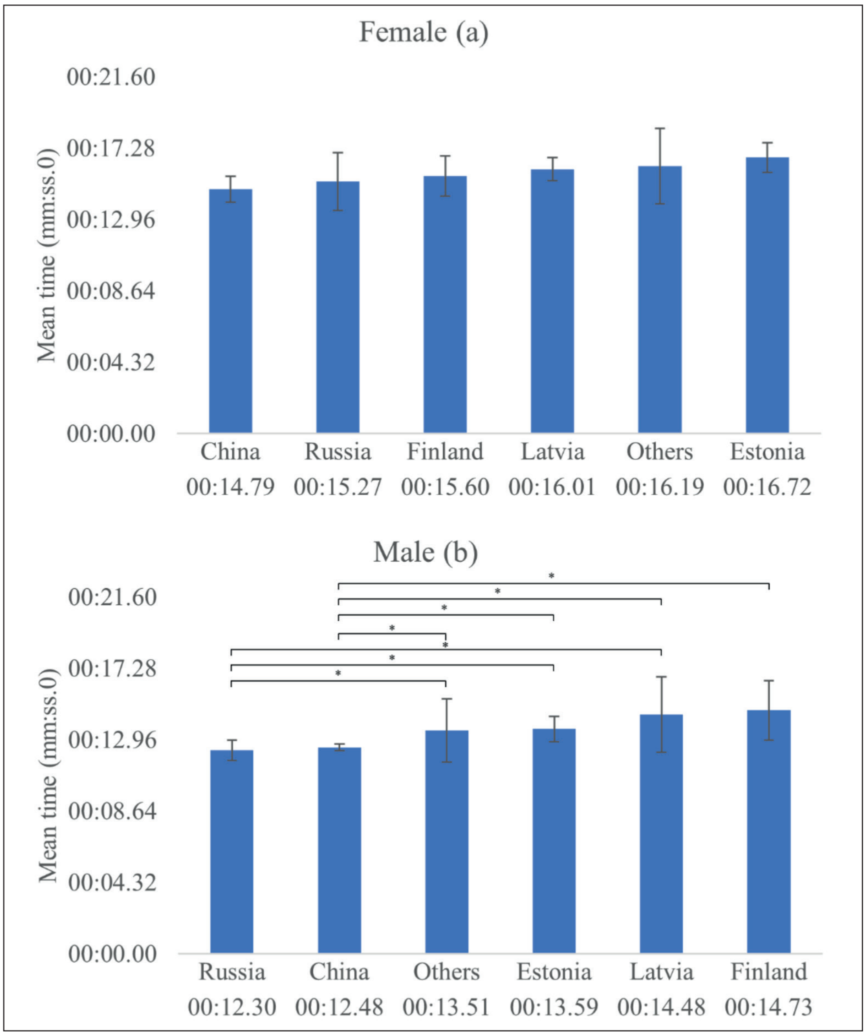

Figure 2. Mean race times and significant differences among nationalities regarding the top 10 samples.

age group of under 15 years old swimmers, (iv) there were more male than female participants, (v) among the five nationalities with the highest numbers of participants Finland was the only country with more female than male participants, (vi) Russia presented significantly faster times than the other countries for females considering the entire sample except for Estonia, (vii) Russia and Estonia presented significantly faster times than the other countries for males considering the entire sample, (viii) there were no differences among the countries in the 25 m races for females considering the top 10 samples, and (ix) Russia and China presented significantly faster race times than the other countries for males considering the top 10 samples.

Male athletes presented significantly faster race times than females in all water categories in the 25 m events. In pool swimming, male athletes were reported to be faster than women due to their taller stature[23,24], longer stroke lengths[23-25] and higher stroke rates[25]. However, it was shown that women could close the gap to male open water swimmers over long distances, especially in cold conditions[17,20,26]. This can be explained by the different anthropometric parameters of body fat percentage and distribution in women compared to men. The higher body fat percentage and unalike distribution of fat resulted in more buoyancy and fewer drag forces in female long-distance open water swimming compared to men[40,41]. However, this does not account for smaller distances in cold water, as the results of this study showed. Furthermore, studies investigating the IISA Ice Mile and Ice Km showed that men were faster than women and that a high BMI with increased body fat may

Table IV. Total female sample mean times, confidence interval and differences between age-groups in 25 m swimming all water temperatures and styles between 2016 and 2020.

Age group (years old)	No. of participants (n=2,676)	Mean time (s)	IC 95%			Differences*
<15	102	00:21.69	00:20.65	to	00:22.73	15-19; 20-29; 45-49; 50-54; 55-59; 60-64; 65-70; 71-74; 75-79; 80 or older
15-19	103	00:18.77	00:17.88	to	00:19.65	30-39; 40-44; 45-49; 50-54; 55-59; 60-64; 65-70; 71-74; 75-79; 80 or older
20-29	282	00:19.40	00:18.85	to	00:19.96	30-39; 40-44; 45-49; 50-54; 55-59; 60-64; 65-70; 71-74; 75-79; 80 or older
30-39	298	00:22.65	00:22.02	to	00:23.28	45-49; 50-54; 55-59; 60-64; 65-70; 71-74; 75-79; 80 or older
40-44	277	00:22.57	00:21.92	to	00:23.22	45-49; 50-54; 55-59; 60-64; 65-70; 71-74; 75-79; 80 or older
45-49	303	00:24.96	00:24.27	to	00:25.64	60-64; 65-70; 71-74; 75-79; 80 or older
50-54	354	00:25.79	00:25.13	to	00:26.44	60-64; 65-70; 71-74; 75-79; 80 or older
55-59	347	00:26.49	00:25.80	to	00:27.17	60-64; 65-70; 71-74; 75-79; 80 or older
60-64	269	00:30.13	00:29.25	to	00:31.01	71-74; 75-79; 80 or older
65-70	167	00:31.84	00:30.66	to	00:33.02	71-74; 75-79; 80 or older
71-74	126	00:35.81	00:34.28	to	00:37.34	75-79
75-79	36	00:45.61	00:41.98	to	00:49.24	
80 or older	12	00:43.54	00:37.54	to	00:49.54	

$p < 0.05$

Table V. Total male sample mean times, confidence interval and differences between age-groups in 25m swimming all water temperatures and styles between 2016 and 2020.

Age group (years old)	No. of participants (n=3,081)	Mean time (s)	IC 95%			Differences*
<15	99	00:22.14	00:21.10	to	00:23.19	15-19; 20-29; 30-39; 40-44; 45-49; 50-54; 71-74; 75-79; 80 or older
15-19	181	00:16.51	00:15.95	to	00:17.08	30-39; 40-44; 45-49; 50-54; 55-59; 60-64; 65-70; 71-74; 75-79; 80 or older
20-29	333	00:16.02	00:15.61	to	00:16.43	30-39; 40-44; 45-49; 50-54; 55-59; 60-64; 65-70; 71-74; 75-79; 80 or older
30-39	544	00:18.42	00:18.05	to	00:18.79	50-54; 55-59; 60-64; 65-70; 71-74; 75-79; 80 or older
40-44	383	00:18.48	00:18.04	to	00:18.92	50-54; 55-59; 60-64; 65-70; 71-74; 75-79; 80 or older
45-49	469	00:19.34	00:18.93	to	00:19.76	55-59; 60-64; 65-70; 71-74; 75-79; 80 or older
50-54	480	00:19.62	00:19.20	to	00:20.03	55-59; 60-64; 65-70; 71-74; 75-79; 80 or older
55-59	421	00:21.29	00:20.81	to	00:21.78	65-70; 71-74; 75-79; 80 or older
60-64	410	00:22.22	00:21.71	to	00:22.73	71-74; 75-79; 80 or older
65-70	248	00:23.64	00:22.94	to	00:24.34	71-74; 75-79; 80 or older
71-74	146	00:27.48	00:26.42	to	00:28.54	80 or older
75-79	59	00:29.11	00:27.35	to	00:30.87	80 or older
80 or older	28	00:37.52	00:34.23	to	00:40.82	

$p < 0.05$

Table VI. Top 10 race times in each water category by sex.

	Sex Female		Male		
Category	***n* (%)**	**Mean time**	***n* (%)**	**Mean time**	***p*-value***
Ice water	40 (50)	00:16.27± 00:02.61 (00:13.10/00:22.85)	40 (50)	00:13.47 ± 00:02.08 (00:10.96/00:18.61)	<0.001
Freezing water	40 (50)	00:14.92 ± 00:00.74 (00:13.16/00:16.06)	40 (50)	00:12.30 ± 00:00.35 (00:11.20/00:12.74)	<0.001
Cold water	30 (50)	00:16.03 ± 00:01.40 (00:14.04/01:18.98)	(50) 30	00:13.16 ± 00:00.89 (00:12.04/00:15.23)	<0.001

Table VII. Top 10 female sample mean times and confidence interval between age-groups in 25 m swimming all water temperatures and styles between 2016 and 2020.

Age group (years old)	No. of participants (n=110)	Mean time (s)			IC 95%*
<15	4	00:15.80	00:14.23	to	00:17.37
15-19	19	00:15.28	00:14.58	to	00:15.98
20-29	53	00:15.44	00:15.01	to	00:15.86
30-39	16	00:16.37	00:15.55	to	00:17.19
40-44	7	00:15.60	00:14.40	to	00:16.80
45-49	2	00:16.20	00:13.95	to	00:18.45
50-54	3	00:16.99	00:15.03	to	00:18.95
55-59	5	00:17.64	00:16.00	to	00:19.27
60-64	1	00:13.71	00:11.04	to	00:16.39

Table VIII. Top 10 male sample mean times, confidence interval and differences between age-groups in 25m swimming all water temperatures and styles between 2016 and 2020.

Age group (years old)	No. of participants (n=110)	Mean time (s)	IC 95%			Differences
15-19	14	00:13.31	00:12.76	to	00:13.86	50-54
20-29	38	00:12.38	00:12.07	to	00:12.69	40-44; 50-54
30-39	40	00:12.60	00:12.29	to	00:12.91	40-44; 50-54
40-44	8	00:13.91	00:13.14	to	00:14.68	
45-49	2	00:14.06	00:12.53	to	00:15.59	
50-54	7	00:15.72	00:14.79	to	00:16.65	
55-59	1	00:14.94	00:12.64	to	00:17.24	

$p < 0.05$

not be beneficial[41]. For sprint distances, a high level of muscle tissue and lower body fat resulted in an enhanced performance in female swimmers[42]. Further research could be carried out to determine the optimal anthropometric characteristics of a winter swimming sprint athlete.

The study results did not support the hypothesis that athletes in the age group 30-39 years have the fastest swimmers. The hypothesis was based on recent studies of the 3000 m FINA open water races where the fastest swimmers were 35-39 years old[9]. Furthermore, it is known that experience in open water swimming and cold habituation is an essential factor for the performance in winter swimming[11,43,44]. Accordingly, it was postulated that the experienced swimmers, thus older swimmers, would be faster than younger and inexperienced swimmers. Although the hypothesis could not be confirmed, this study's fastest overall age group was between 15 and 29 years. This result confirms studies reporting the peak performance in pool swimming at around 20 years of age[45] and in open water swimming at the age of 22-28 years[46]. Interestingly, female swimmers have their peak performance at a younger age than males[46,47]. This is confirmed in the present study as females were the fastest at 15-19 years and males at 20-29 years. It is known that after the peak of performance, swimming performance decreases with increasing age[48-50], which could be the reason why swimmers in the age group 30-39 years were eventually slower than expected. However, this process might be mitigated with consistent training[49]. Further research could investigate the start of the careers of young international winter swimmers to compare how many years of experience in swimming and cold habituation are needed to reach the peak of performance.

In open-water swimming, the smallest sex gap in performance was reported to be in the age groups of under ten years old[51], and over 75 till 80 years old swimmers[17]. The present study identified the closest sex gap for the youngest age group of under 15 years old swimmers. This might be due to hormonal reasons. A higher number of circulating androgens in male swimmers after puberty is advantageous for their swimming performance compared to females. Thus, equal levels of androgens before puberty could be the reason for the narrow sex gap in young swimmers[51]. However, from the age of 10 years on, the sex differences are reported to increase, and the levels of androgens also increase considerably in males after puberty[51]. For the older age groups (70-79 years old and over 80 years old), the aforementioned close sex gap could not be confirmed; as in the present study, the sex gap was rather remarkable. Further research in endocrine and anthropometric characteristics of under 15 years old winter swimmers should be conducted to explain the narrow sex gap.

It is known that male athletes have higher participation in sports than females[16]. However, woman's participation in sports increased dramatically in the 20th century in almost all sports disciplines[16,52]. In open water swimming, this trend has been reported for the events of 'La Traversée Internationale du Lac St-Jean' (1955-2012)[22] and 'The Triple Crown of Open Water Swimming' (1875-2017)[8]. Regarding the present study, male swimmers had a higher participation rate than female swimmers considering participation of the overall events. It can be assumed that with increasing numbers of participants in winter swimming, women can close the performance gap to male athletes, especially when comparing the overall events. Further research should be conducted regarding sex differences in the evolution of participation in winter swimming.

Interestingly, Finland was the only country, among the five countries with the highest numbers of participants in all events, with more female than male participants. Finnish female athletes did not perform significantly better than swimmers from the other nationalities. Still, among the top ten athletes, they had the closest sex gap in performance to the male athletes for the five countries with the highest participants. Therefore, it can be suspected that a narrowing in the participation gap also leads to a narrowing in the performance gap. Further research could show if the gap between male and female Finish athletes is significantly closer than in the other countries. A study[53] of the improvement of general wellbeing in relation to winter swimming conducted in Finland also showed a higher amount of female participants. Therefore, it would be interesting to investigate how winter swimming was promoted for female swimmers in Finland and why they have a higher participation rate than males.

Russian and Estonian male and Russian female winter swimmers were significantly faster than swimmers from other nations. This contrasts our hypothesis that there would be no overall dominating nation in these events. One explanation for the Russian and Estonian dominance could be that Russia had the highest number of participants and Estonia had the third most participants. This supports our second hypothesis that the countries with the highest number of participants would also be the countries with the fastest winter swimmers. However, athletes from Finland, with the second most participants, did not perform accordingly. An investigation of the 3000 m FINA World Master Championships between 1992 and 2019 showed similar results[9]. In this case, Italy had the most participants and Italians were also the fastest swimmers in these competitions worldwide.

In international events, the accessibility of the events plays a significant role. It is known that in open-water swimming, there is often a high number of athletes from the hosting nation[5,8,9]. In the present study, 20% of the events were hosted in Russia and 10% in Estonia. This indicates the excellent accessibility, especially for Russian athletes, which could be a reason for the high number of Russian participants. The number of athletes from the hosting nation was probably exaggerated in 2019-2020 due to the COVID-19 pandemic. The IWSA encouraged athletes to attend geographically close events primarily[54].

A high popularity and a long tradition of a sports discipline in distinct areas were shown to be a factor for the athletes' success[27,28]. This could explain the results of Russian and Estonian winter swimmers. In Russia, for example, winter swimming is a part of the orthodox epiphany celebrated by millions of Russians every year on the 19th of January[55,56]. In addition to that, the Russian traditional 'Walrus' ice swimming clubs gained more and more popularity, where recreational winter swimming is performed weekly[57]. In Estonia, winter swimming emerged from the long sauna tradition of the Estonians[58]. Therefore, further research should investigate distinct areas in Russia and Estonia where many international winter swimmers originate.

In the top 10 samples of this study, Russian and Chinese men presented significantly faster race times over the 25 m distance than the other countries. Interestingly, Russian women who were also significantly faster than the other nations in the overall sample were not significantly faster than the others in the top 10 samples. In fact, in the women's top 10 samples, no significant differences were detected among the countries. This could be explained by the lower numbers of participation of women compared to men. However, all nations reported lower numbers of female athletes except for Finland.

It is known that large population nations outperform smaller nations in international sports events[59,60]. The outstanding performance of Russian and Chinese male winter swimmers could be attributed to the large population of the countries. China has a population of 1.4 billion people while Russia has 145 million inhabitants[61]. Although Estonia has only a small population, they were the overall fastest male athletes together with Russia. Research showed that small countries could close the gap by promoting sports disciplines and increasing the number of participants[59]. In this study, the analysis of the participation in the events was performed. Further research could investigate the number of winter swimmers of the leading nations.

Another explanation for the Russian and Chinese dominance among the top 10 finishers could be the work of national swimming federations and associations. The 'St. Petersburg Winter Swimming Federation' is promoting winter swimming, especially for the young population, by reviving the old winter swimming traditions[62]. They work together with the IWSA recreating the competition conditions for training and national and international events (e.g., Big Neva Cup). The best athletes are selected to take part in national and international events. Furthermore, they offer a Master's program and the highest safety conditions and education. President Roman Karchev is also a board member of the IWSA, securing cooperation with the IWSA[62]. The professional preparation under competition conditions, the selection of the best athletes from a large mass of winter swimmers and the cooperation with the IWSA could explain the outstanding results of Russian male winter swimmers over 25 m. In the past, Russian Governmental support of mass and elite sport, including pool swimming, already improved Olympic success and national health[63]. In addition, Russia already had the fastest athletes in other extreme sports like ultra-marathon running and long-distance cross country skiing[34], showing Russian expertise in extreme sports in general. Further research could reveal why the women did not succeed, as they are profiting from the excellent work of the associations in the same way as men.

In China, the Zaozhunang municipal sports bureau and the Taierzhuang district government work with the IWSA to hold the 'International Taierzhuang Winter Swimming Festival'[64]. They were also holding the 'Taierzuhang Winter Swimming World Cup' in 2017, included in this study[3]. Another example is the 'Lanzhou Winter Swimming Association', which, with the help of the municipal government, provides several professional training stations for their members in the yellow river[65]. The association has a 30 years long history and increased the number of members from a few to almost 400 during that time[65,66]. The most active train five times a week and are selected for international winter swimming events[65,66]. The Chinese Swimming Association has implemented a Winter Swimming Committee to improve further the management of winter swimming activities in China[67]. It was already shown that the high importance of sport in China's policy increased elite sport success in the last years68. This could explain the superior performance of male Chinese winter swimmers among the top 10. Further research should investigate why Chinese women were not as successful as the men among the top 10 and why China was not as assertive in performance as Russia and Estonia in the entire sample.

A limitation of the present study is that in addition to the 25 m sprint distance races, the 50 m and 100 m distance races were not included. Furthermore, not all environmental conditions (e.g., currents, wind, waves) were considered except for the water temperature, although they can affect the performance[40]. Lastly, the percentage of local athletes per event was not considered, giving a more detailed interpretation of the participation trends.

Conclusions

In summary, in the IWSA World Cups between 2016 and 2020, male athletes were significantly faster than females in all water categories. The age group of 15-29 years old athletes was the most successful while females had their peak of performance earlier than males. The sex gap in performance was closest in the age group of under 15 years old athletes. Russian and Estonian males and Russian female athletes were the overall fastest in the 25 m events in all water categories. On the other hand, Russian and Chinese males were the fastest in all water categories in the top 10 section in the 25 m events. Future studies should investigate the optimal anthropometric parameters of male and female winter swimming sprint athletes and whether there are distinct areas in Russia, Estonia and China, where many international winter swimming athletes originate.

Conflict of Interest

The Authors declare that they have no conflict of interest.

Authors' Contributions

Conceptualization, Beat Knechtle; methodology, Beat Knechtle and Lucas Zimmermann; formal analysis, Marilia Santos Andrade, Aldo Seffrin, Rodrigo Luiz Vancini and Claudio Andre Barbosa de Lira; data curation, Beat Knechtle, Janne Oppermann and Lucas Zimmermann; writing—original draft preparation, Beat Knechtle and Lucas Zimmermann.; writing—review and editing, Lee Hill and Piotr Gronek; All authors have read and agreed to the published version of the manuscript."

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Institutional Review Board Statement

The study was conducted according to the guidelines of the Declaration of Helsinki. 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 participant as the study involved the analysis of publicly available data (EKSG 01-06-2010).

Informed Consent Statement

Not applicable.

Data Availability Statement

The data set of this study was collected from the official IWSA website.

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