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FREESTYLE VERSUS BUTTERFLY SWIMMING PERFORMANCE – EFFECTS OF AGE AND SEX

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ABSTRACT
Purpose. Recent studies have suggested that the age of peak freestyle swimming speed is reached earlier in life in women than in men. However, no study has investigated the age of peak swimming speed in other swimming styles such as butterfly. The aims of the present study were to investigate the age of peak swimming speed in elite male and female butterfly and freestyle swimmers at the national level (Switzerland) and the sex differences in both the age of peak swimming speed and swimming speed for both swimming styles. **Methods.** Results of the elite Swiss swimmers between 2006 and 2010 were analysed using one-way analysis of variance. **Results.** In butterfly, women achieved peak swimming speed at 20–21 years in the 50 m, 100 m and 200 m, whereas men reached their fastest swimming speed in the 50 m at 20–21 years and in both the 100 m and 200 m at 18–19 years. In freestyle, women achieved peak swimming speed at 20–21 years for all distances. Men were the fastest at 22–23 years for both the 100 m and 200 m and at 26–27 years for the 50 m. In the butterfly, the sex difference in swimming speed was highest in the 50 m and lowest in the 200 m (14.1% ± 0.2 in the 50 m, 12.6% ± 1.0 in the 100 m and 8.7% ± 1.8 in the 200 m). Additionally, the sex difference in freestyle swimming speed was highest in the 50 m and lowest in the 200 m (16.2% ± 0.5 in the 50 m, 15.9% ± 0.4 in 100 m and 14.9% ± 1.0 in 200 m). **Conclusions.** These findings suggest that peak swimming speed was achieved earlier in life in men compared with women for the 100 m and 200 m butterfly distances but not in the 50 m butterfly. In freestyle, peak swimming speed was achieved at younger ages in women compared with men. The sex difference in peak swimming speed was lower in the butterfly than in freestyle.

Key words: sex difference, swimming, athlete, age of peak performance

Introduction

Generally, athletic performance decreases after a certain age threshold is reached [1–3]. In swimming, peak freestyle swimming speed is maintained up to the age of 35–40 years, with a linear decrease in swimming speed thereafter until the age of ~70 years, whereby it then decreases exponentially [2]. For both women and men the decrease in top swimming speed is congruent until the age of ~70 years [2–4].

For freestyle swimming, the age-related decline in swimming speed has been found to show differences in regards to the length of the swimming distance and sex [2, 3]. The age-related decline in swimming speed was greater in the 1500 m than in the 50 m and was greater in women than in men in the 50 m [2]. In women, the decline in swimming speed increased progressively from the 50 m to 800 m and then 1500 m distances. In men, no differences were observed in swimming speed decline between the 100 m and 1500 m freestyle [3].

For coaches and athletes, the age of peak swimming speed may be of higher interest than the age-related decline in swimming speed. Knowledge of the age of peak swimming speed would offer an estimate when swimming speed starts to decrease in elite swimmers. Additionally, elite swimmers past the age of peak swimming speed could either then begin to concentrate on aspects outside professional sport or become involved in other disciplines or race distances.

It has been reported that the age of peak swimming speed for athletes competing in different disciplines and over different distances has remained relatively stable across time [4–6]. Schulz and Curnow [6] analysed the results of Olympic track and field athletes and swimmers from 1896 to 1980. They presented data of age and peak performance of Olympic gold medal winners and showed that the age of the men's 100 m running sprint from 1896 to 1980 remained relatively stable. For swimmers, Berthelot et al. [1] described the age of peak performance of swimmers aged ~21 years. Fairbrother [4] reported the age of peak performance for 50 m freestyle swimmers to be in the late 20s and early 30s for men.

However, in freestyle swimming, evidence pointed to differences in the age of peak performance in regards to the length of the race distance. Peak performance in the 1500 m was achieved at a younger age of ~18 years compared with the age of ~23 years for the 50 m [4]. The age of peak freestyle performance also seemed to be different between women and men. Schulz

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and Curnow [6] reported that women generally achieved peak freestyle performance at younger ages than men. Furthermore, a longer freestyle distance was associated with a lower age of peak swimming performance. Schulz and Curnow [6] analysed data of Olympic freestyle swimmers competing in the 100 m, 400 m and 1500 m for men and the 100 m, 400 m and 800 m for women. The age of peak freestyle performance was between 21.4 years (100 m) and 20.3 years (1500 m) in men and between 19.4 years (100 m) and 16.0 years (800 m) in women.

Therefore, women seem to reach their age of peak freestyle swimming performance at a younger age compared with men. However, Tanaka and Seals [3] reported different findings, showing that men reached their fastest swimming times for the 1500 m freestyle between 25 and 40 years whereas women achieved their fastest 1500 m freestyle times at 30–35 years of age. In contrast, peak swimming performance in the 50 m freestyle was achieved at the age of 20–30 years in both women and men [3].

As shown above, the age of peak swimming performance has been investigated for freestyle pool swimmers for distances between 50 m to 1500 m [2–5]. However, these reports showed different results for the age of peak freestyle swimming performance and some were evaluating rather old data from time periods such as 1896–1980 [6], 1988–1999 [2], 1991–1995 [3] and 1993–2001 [5]. Additionally, these studies did not include swimmers in the 10–18 year age group in their analyses. Donato et al. [2] investigated athletes aged from 19–85 years, Fairbrother [5] from 19–96 years and Tanaka and Seals [3] from 19–99 years. Since Schulz and Curnow [6] showed that the age of peak freestyle swimming performance was at ~20 years or below in women, the studies of Donato et al. [2], Fairbrother [5] and Tanaka and Seals [3] most probably did not determine the correct age of peak freestyle swimming performance due to their exclusion of 10–18 year old freestyle swimmers from analyses.

To date, most studies investigated freestyle pool swimming, which can be practised from the 50 m distance [6] to 12 h ultra-swimming events [7] and most likely even beyond. Since swimming is performed in different styles (strokes), there may be a difference in peak swimming speed and a sex difference over the same distance depending on used stroke, such as the butterfly, backstroke, breaststroke and medley. For example, butterfly pool swimming is generally practised from 50 m to 200 m or as part of the 400 m medley. However, no study has so far investigated the age of butterfly peak swimming speed in the 50 m, 100 m and 200 m. Since the results for the age of peak freestyle swimming performance were inconsistent [3, 6], it was decided to investigate butterfly swimming results and compare them with freestyle swimming results over the same time period from swimmers of the same country.

The aims of the present study were to therefore investigate (*i*) the age of peak swimming speed for both male and female top swimmers at a national level for butterfly at the 50 m, 100 m and 200 m distances and compare them with their freestyle results for the 50 m, 100 m and 200 m distances and (*ii*) analyse the sex difference of the age of peak swimming speed. We hypothesised that (*i*) the age of peak swimming speed would be lower in women compared with men for both styles and (*ii*) that the sex difference in swimming performance would decrease with increasing race distance for both styles.

Material and methods

All procedures used in the study met the ethical standards of the Swiss Academy of Medical Sciences [8] and were approved by the Institutional Review Board of the Canton of St. Gallen, Switzerland, with a waiver provided for the requirement of participants' informed consent given the fact that the study involved the analysis of publicly available data.

The data set from this study was obtained from the website of the Swiss Swimming Federation [9]. The high score list of the Swiss Swimming Federation annually records the fastest race times of each swimmer for all distances and strokes in both short course and long course races [9]. Data were available from 50519 athletes, including 24656 women and 25863 men. No swimmer is listed two or more times in this high score list. The original sample consisted of all swimmers from the Swiss swimming high score list between 2006 and 2010 in long course butterfly and freestyle swimming and were analysed regarding age and swimming speed in the 50 m, 100 m and 200 m.

In order to facilitate data analysis and to make the race results more comparable, mean race times were transformed to swimming speed (m/s) prior to statistical analysis by calculating swimming speed (m/s) = [race time (s)]/[race distance (m)]. For the analysis of swimming speed by age, all athletes were separated by sex and categorised into 10-year age groups: <10, 10–19, 20–29, 30–39, 40–49, 50–59, 60–69 and 70–79 years. For each age group and sex, the annual three fastest swimming speeds per race distance were determined. The selection of the fastest three speeds for each 10-year age group allowed us to include as many age groups as possible until reaching the more advanced ages.

The swimming speed of these annual top three athletes for the entire five-year period under consideration showed no significant difference in a year-by-year analysis using one-way analysis of variance (ANOVA). Therefore, these 15 athletes per age group were pooled. From these 15 athletes, again the top three per sex, race distance and age group were determined. In the case that less than three swimmers were listed in an age group, this specific age group was excluded from data analysis.

Afterwards, these data were analysed regarding swimming speed between age groups. During this stage of analysis, the age groups showing the fastest swimming speed were the 10–19 and 20–29 year-old age groups for both women and men, with the exception of 30–39 year-old age group for the 50 m freestyle in women. It was therefore decided to analyse these two age groups (10–19 and 20–29) in more detail using 2-year age intervals. All athletes between 10–29 years were divided into 2-year age groups (i.e. 10–11, 12–13, 14–15, etc.). For each of these age groups the top three athletes for sex and race distance were determined and compared against each other in regards to differences in swimming speed.

In order to increase the reliability of data analyses, each data set was tested for normal distribution as well as for homogeneity of variance prior to statistical analyses. Normal distribution was tested with the D'Agostino-Pearson omnibus test and homogeneity of variance was tested with Levene's test for two groups or with Bartlett's test for more than two groups. To find significant differences between groups, one-way ANOVA with the Tukey-Kramer post-hoc method was used. Statistical analyses were performed using SPSS Statistics ver. 19 software (IBM, USA) and GraphPad Prism ver. 5, (GraphPad Software, USA). Significance was accepted at $p < 0.05$ for two-tailed t tests. Data in the text are given as means and standard deviations (*SD*).

Table 1. *F* values for Figures 1–4

Figure	Sex	Distance	*F* value
1	female	50 m	84.12
	female	100 m	98.08
	female	200 m	10.55
	male	50 m	208.6
	male	100 m	89.22
	male	200 m	233.9
2	female	50 m	25.64
	female	100 m	7.416
	female	200 m	22.49
	male	50 m	94.92
	male	100 m	105.2
	male	200 m	24.44
3	female	50 m	35.13
	female	100 m	46.55
	female	200 m	70.30
	male	50 m	205.7
	male	100 m	127.3
	male	200 m	141.7
4	female	50 m	8.605
	female	100 m	11.94
	female	200 m	9.350
	male	50 m	94.96
	male	100 m	125.1
	male	200 m	62.83

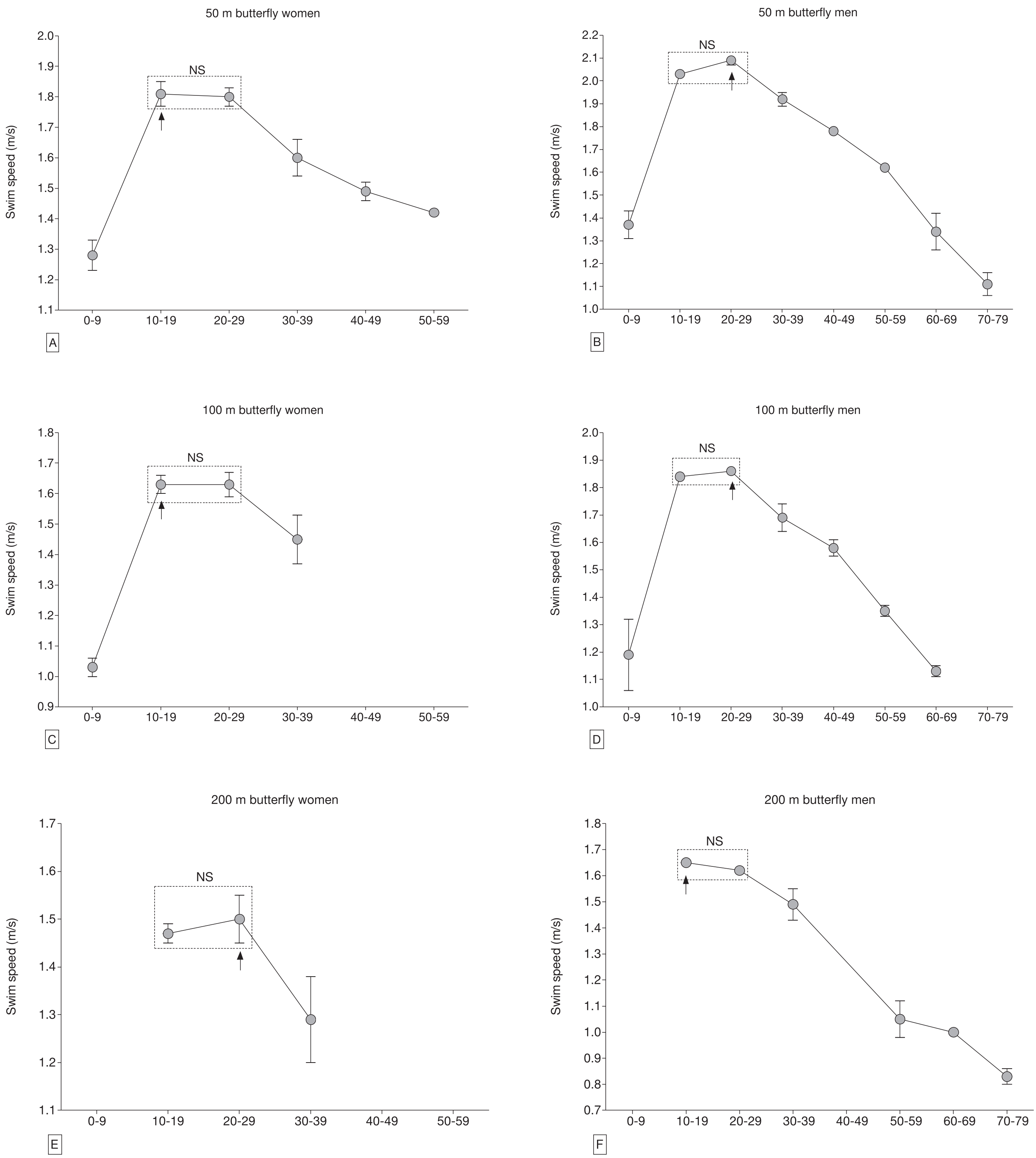
Results

Figure 1 presents the age of peak swimming speed in the butterfly per the 10-year age intervals and Figure 2 per the 2-year age intervals. Figures 3 and 4 show the same results for freestyle. Table 1 presents the *F* statistic values of the ANOVA tests, whereas Table 2 shows the mean peak swim speeds and age of peak swim speeds of the fastest three athletes for distance and sex in the butterfly and freestyle.

Among the 10-year intervals for the butterfly, peak swimming speed was achieved in the 10–19 and 20–29 year age groups for both men and women and for all distances (Fig. 1). When the 10–19 and 20–29 age groups were analysed in 2-year intervals, women achieved peak swimming speed at the age of 20–21 years for the 50 m, 100 m and 200 m (Fig. 2). Men achieved the fastest swimming speed for the 50 m at the age of 20–21 years,

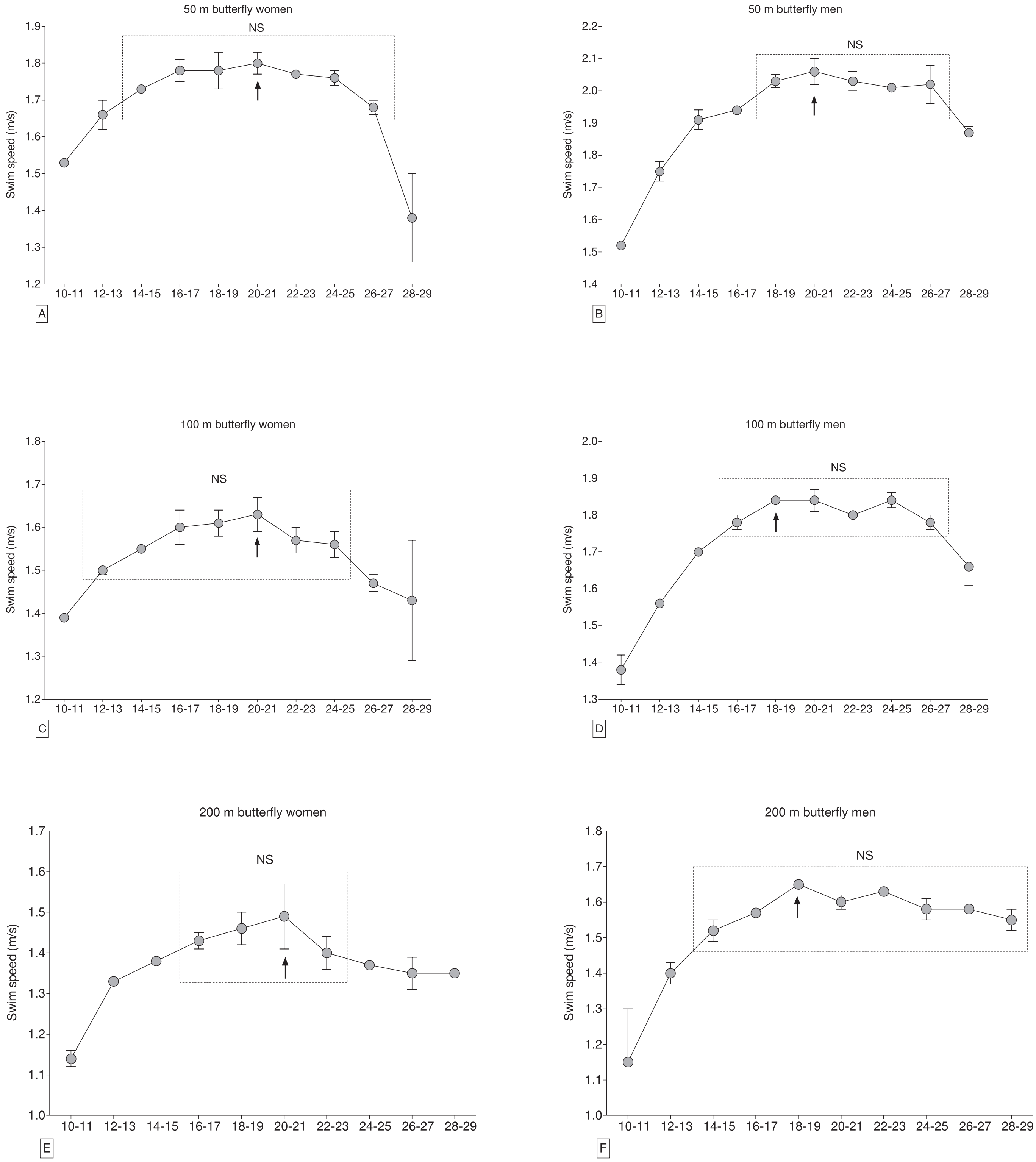
Table 2. Peak swim speed and age of peak swim speed (mean ± *SD*) of the fastest three swimmers for distance and sex in both butterfly and freestyle from 2006–2010

Distance (m)	Peak swimming speed (m/s)			
	butterfly		freestyle	
	women	men	women	men
50	1.8 ± 0.0	2.1 ± 0.0	1.9 ± 0.0	2.2 ± 0.0
100	1.7 ± 0.0	1.9 ± 0.0	1.8 ± 0.0	2.0 ± 0.0
200	1.5 ± 0.0	1.6 ± 0.0	1.6 ± 0.0	1.9 ± 0.0
Distance (m)	Age of peak swimming speed (years)			
	butterfly		freestyle	
	women	men	women	men
50	18.3 ± 2.1	22.3 ± 3.2	20.0 ± 1.0	21.7 ± 4.2
100	18.3 ± 2.1	22.0 ± 2.6	19.7 ± 1.2	24.3 ± 1.5
200	19.7 ± 1.5	18.3 ± 0.6	23.7 ± 3.2	24.0 ± 1.0



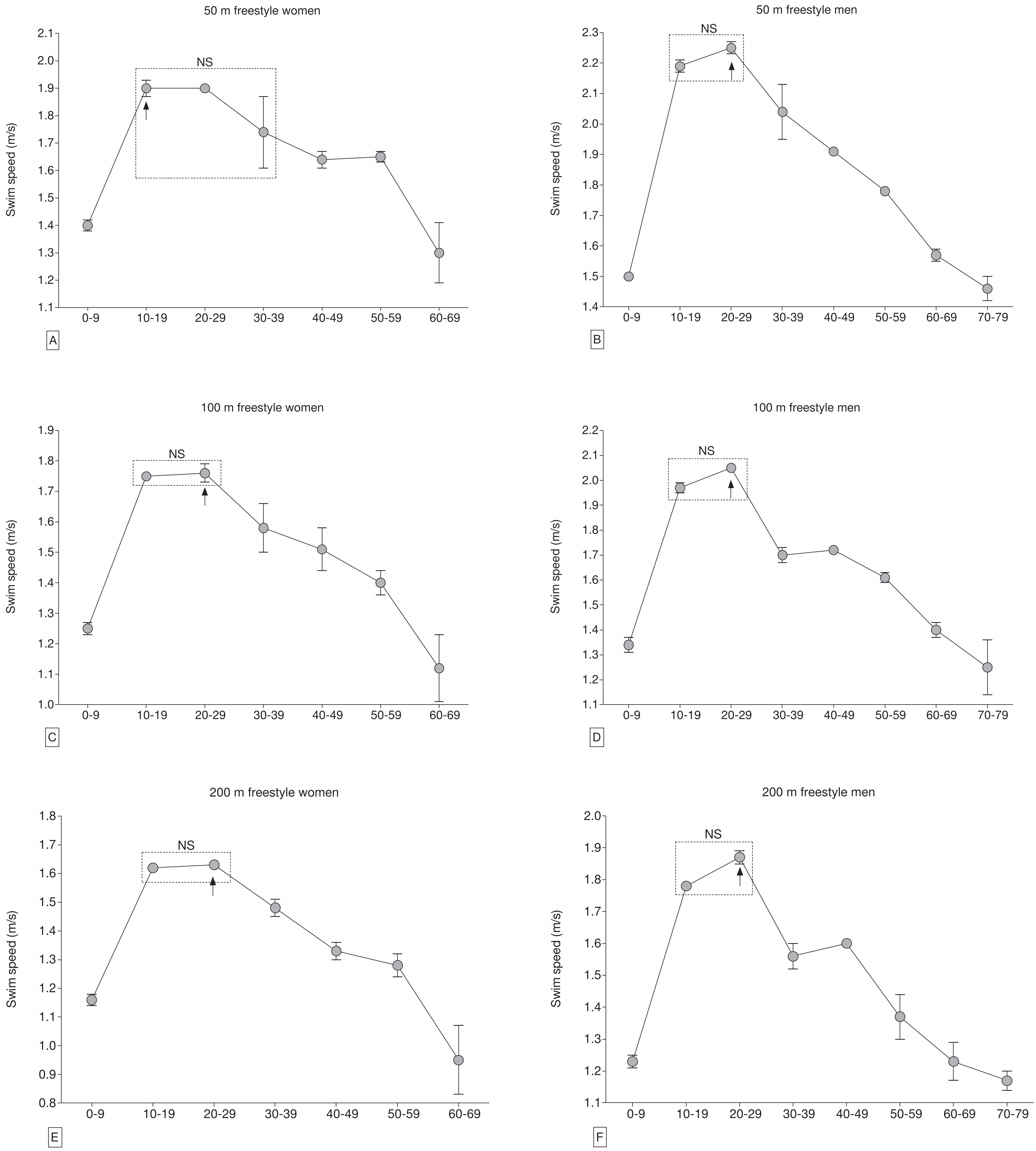
Age groups with no significant difference in swimming speed are indicated by a rectangle and marked with 'NS'

Figure 1. Swimming speed of the three fastest female (A, C, E) and male (B, D, F) swimmers between 2006 and 2010 in 10-year age groups for the 50 m (A, B), 100 m (C, D) and 200 m (E, F) butterfly



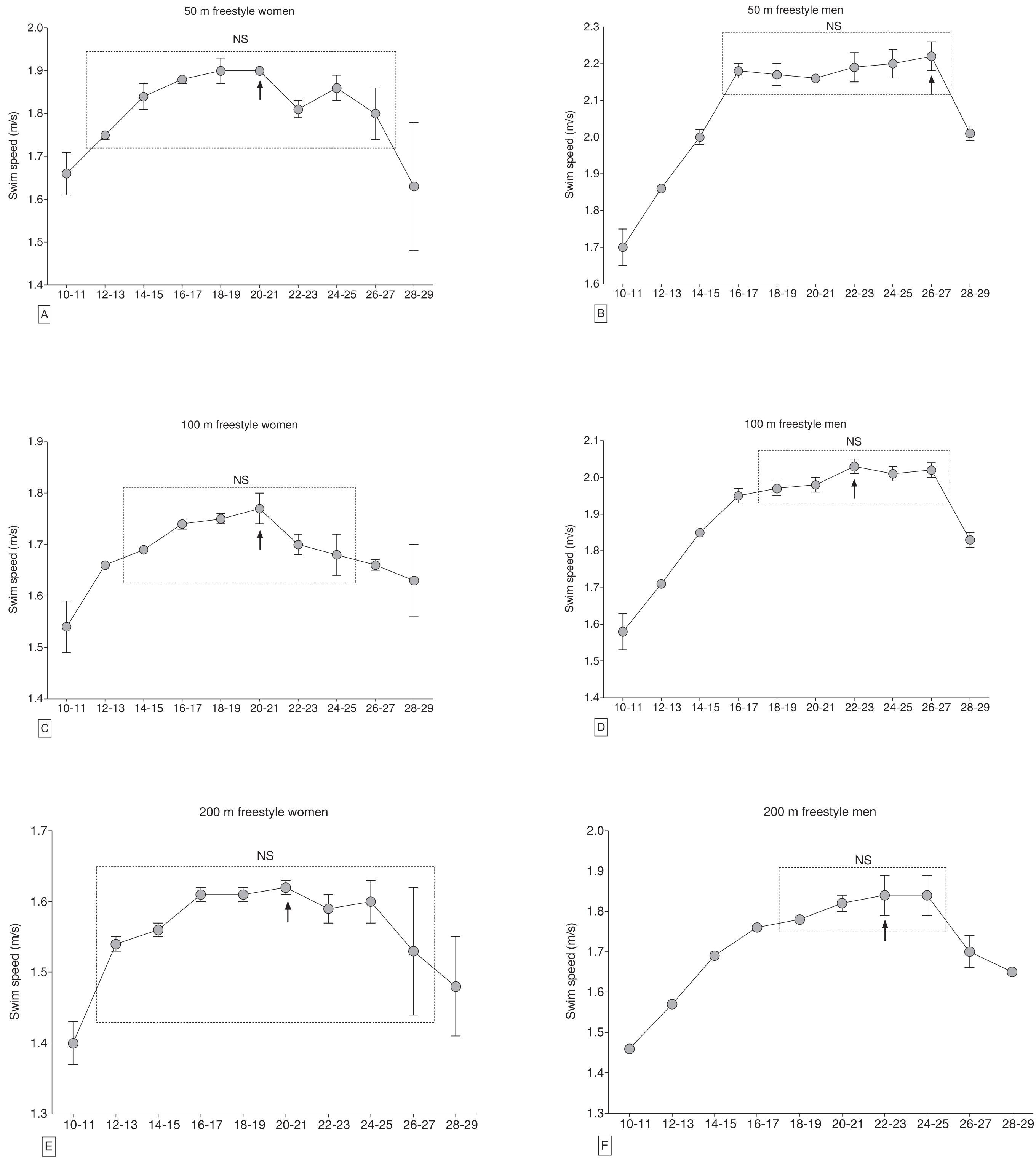
Age groups with no significant difference in swimming speed are indicated by a rectangle and marked with ‘NS’

Figure 2. Swimming speed of the three fastest female (A, C, E) and male (B, D, F) swimmers between 2006 and 2010 in 2-year age groups of athletes aged between 10 and 29 years for the 50 m (A, B), 100 m (C, D) and 200 m (E, F) butterfly



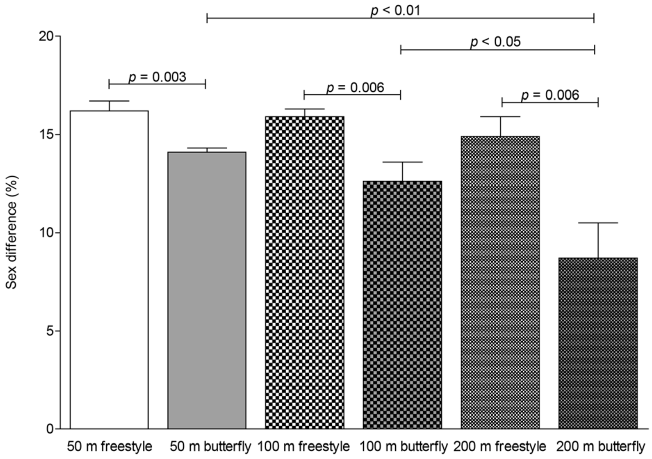
Age groups with no significant difference in swimming speed are indicated by a rectangle and marked with 'NS'

Figure 3. Swimming speed of the three fastest female (A, C, E) and male (B, D, F) swimmers between 2006 and 2010 in 10-year age groups for the 50 m (A, B), 100 m (C, D) and 200 m (E, F) freestyle



Age groups with no significant difference in swimming speed are indicated by a rectangle and marked with 'NS'

Figure 4. Swimming speed of the three fastest female (A, C, E) and male (B, D, F) swimmers between 2006 and 2010 in 2-year age groups of athletes aged between 10 and 29 years at the 50 m (A, B), 100 m (C, D) and 200 m (E, F) freestyle



p values indicate distances and disciplines significantly different from each other

Figure 5. Sex difference between the three fastest men and women at the national level (Switzerland) between 2006 and 2010 for discipline and distance

but at 18–19 years for the 100 m and 200 m (Fig. 2, Tab. 2).

In freestyle, men achieved peak swimming speed in the 10–19 and 20–29 year age groups for all distances (Fig. 3). For women, peak swimming speed was achieved in the 10–19, 20–29 and 30–39 year age groups for the 50 m (Fig. 4). For the 100 m and 200 m, peak swimming speed was attained in the 10–29 and 20–29 year age groups, respectively. When the 10–19, 20–29 and 30–39 year-old groups were analysed in 2-year intervals, men were fastest at the age of 22–23 years for the 100 m and 200 m and at 26–27 years for 50 m (Fig. 4). Women achieved peak swimming speed at the age of 20–21 years for all distances (Fig. 4, Tab. 2).

For both butterfly and freestyle, the sex difference in swimming speed was highest in the 50 m and lowest in the 200 m. For butterfly swimming, the sex differences of the fastest three swimmers in the 50 m, 100 m and 200 m were 14.1% ± 0.2, 12.6% ± 1.0 and 8.7% ± 1.8, respectively. In freestyle swimming, the sex differences were 16.2% ± 0.5, 15.9% ± 0.4 and 14.9% ± 1.0, respectively. The sex differences were lower in the butterfly compared with the freestyle. In the butterfly, the sex differences in swimming speed differed significantly between the 50 m and 200 m and between the 100 m and 200 m (Fig 5).

Discussion

We intended, firstly, to investigate the age of peak swimming speed of both top male and female Swiss swimmers in the 50 m, 100 m and 200 m freestyle and butterfly during 2006–2010 and, secondly, to analyse the sex differences in swimming performance in both swimming styles. The main findings were (*i*) women achieved peak swimming speed in the 100 m and 200 m butterfly at a younger age compared with men in contrast to freestyle, (*ii*) the sex difference in swimming speed was highest in the 50 m and lowest in the 200 m for both styles and (*iii*) the sex difference in swimming performance was lower for butterfly than for freestyle.

The first important finding was that the age of peak swimming speed was at an earlier age in women compared with men in the 100 m and 200 m butterfly (i.e. 20–21 versus 18–19 years). Maturation and puberty may explain these differences since maturation occurs earlier in women than in men [10, 11]. This can be seen, for example, in bone growth during puberty in relation to physical growth [12]. A maximal increase of all bone variables occurs earlier in girls than in boys and starts with bone width, then mineral content and then density. By the age of 17 years, boys attain 86% of the reference values for adult bone mineral content and volumetric density whereas girls attain 93% of the reference values for adult bone mineral content and 94% for volumetric density. A very recent study on the growth of metacarpal bones showed a difference of ~2 years in the growth pattern between boys and girls [10].

Furthermore, Bitar et al. [13] reported that during the onset of puberty, boys and girls gain fat-free mass albeit this gain was higher in girls than in boys. Lean body mass, which primarily reflects muscle mass, begins to increase during early puberty in both boys and girls. Fat mass, however, increases during the late stages of puberty in girls [11], with the further increase in fat mass after puberty impairing swimming speed in women. Zuniga et al. [14] showed that boy and girl sprint swimmers at the age of ~11 years were differentiated by percent body fat (i.e. boys 9.4% fat and girls 12.7% fat) and suggested that swimming speed for girls may have improved in their study through training programs designed to reduce the percentage of body fat.

Apart from these aspects, motivation may also play a role in sex difference, with Salselas and Márquez [15] reporting that boys in advanced swimming programs perceived a stronger 'success-without-effort climate' created by both their father and mother than did girls at the same level of practice. Therefore, boys seem to be advantaged in terms of motivational support. Even if women presumably wanted to match men in terms of swimming skills, motivation seemed to be of a different origin in women than in men [16].

The second important finding was that the sex difference in the swimming speed of the fastest three swimmers during the analysed period was highest in the shortest race distance and lowest in the longest race distance in both the butterfly (50 m at 14.1%, 100 m at 12.6% and 200 m at 8.7%) and freestyle (50 m at 16.2%, 100 m at 15.9% and 200 m at 14.9%).

Differences in anthropometry between sexes may provide a possible explanation for the decreasing sex difference in swimming speed with increasing length of the race distance. Female swimmers have significantly more adipose tissue than male swimmers [14, 17, 18], where women, in particular, have proportionally more fatty tissue located caudally compared with men whereby the centre of buoyancy is different in men compared with women [17]. The higher and more caudally located body fat may enhance female swimming speed for longer distances such as the 5 km, 10 km or 25 km. However, men have higher peak leg power compared with women [10, 19–22] mainly due to higher lean leg volume [10, 19, 22], peak leg power and lean leg volume with increasing age [10, 19, 23]. This favours men and could compensate for some of the buoyancy effects of fat tissue. Additionally, Seifert et al. [24] analysed the kinematic changes during the 100 m front crawl in both men and women. High-speed swimmers were characterised by a higher and more stable stroke length. The principal sex difference in this regard was the greater stroke length in men compared with women.

Each of these above-mentioned factors may have a different level of influence on the sex difference of swimming speed depending on the course length. However, none address the fact that the sex difference in swimming speed decreased with increasing race distance. Eichenberger et al. found in ultra-endurance swimming races such the 26.4 km Lake Zürich Swim [25], the 12 h swim in Zurich [7] and the 34 km English Channel Swim [26] the same trend, finding only a small to no sex difference in swimming speed. It therefore seems that the sex difference in swimming speed lessens in long-distance swimming competitions.

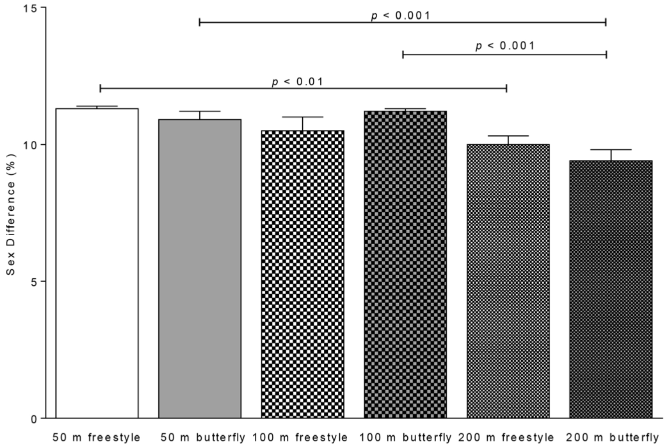
The third main finding was that the sex difference in swimming speed was lower in butterfly than in the freestyle. The average sex difference in swimming speed was 9–14% in the butterfly and 15–16% in freestyle. Higher leg power may explain the difference for peak swimming speed in freestyle [19–22]. Higher and more caudally located body fat may favour the special butterfly movement of pushing the body out of the water. In addition to body fat, body height and length of extremities may also account for these differences [27]. Geladas et al. [28] showed that upper extremity length, the horizontal jump and handgrip strength were identified as significant predictors of 100 m freestyle swimming speed in boys. In girls, body height, upper extremity and hand length, shoulder flexibility and horizontal jump were all significantly related to 100 m freestyle swimming speed [28]. Additionally, Seifert et al. also found that female swimmers feature smaller body height and arm span than male swimmers [24].

Swimming style may also have an influence on swimming speed [29, 30]. Chollet et al. [29] showed that stroke rate increased with increasing pace in butterfly swimming when distances from 50 m to 400 m were compared. Another study on the 200 m butterfly, being a very intense swimming style, found that anthropometric characteristics such as low body fat and high skeletal muscle mass at ages younger than 20 years enhance 200 m butterfly swimming speed [19]. Age has also an effect on the distance covered per stroke. Zamparo [31] investigated the propelling efficiency of the arm stroke in a group of 63 male and female subjects aged 9–59 years with good technical skills swimming the front crawl at sub-maximal swimming speeds. In both sexes, the distance covered per stroke was similar before puberty, reached its maximum at ~20 years of age and then steadily declined, albeit being significantly larger in men than in women. All these factors may have a different influence on swimming speed depending on the length and modality of the swimming style. However, the difference between butterfly and freestyle in terms of sex difference remains unclear.

In other sports disciplines such as running, an increase in sex difference with increasing distance was reported. Coast et al. [32] reported on running distances ranging from 100 m to 200 km, finding a mean sex difference of 12.4% in favour of men and that the sex difference seemed to grow with increasing race distance. Thibault et al. [33] systemically investigated other sports such as athletics, track cycling, weightlifting and speed skating. They reported the sex gap to be constant across years at 10.0% ± 2.9 between men and women for all investigated sports.

Therefore, the decrease in sex difference with increasing race distance in swimming seems to be an exception in regards to other sports disciplines. An important difference between swimming and other sports such as running may be found in the duration of the physical activity. Current world records for both sexes in both butterfly and freestyle are ~2 min [34] and therefore similar in time to the current world record of 800 m track running [35]. Furthermore, there is reason to believe that the sex difference in swimming speed may in fact decrease up to a certain distance and then increase [7, 25, 26]. However, the comparison of swimming to other land-based sports is muted due to influence of the medium of water on numerous aspects such as body density (i.e. lean body mass, fat mass, fat and muscle distribution).

Limitations of the study that need addressing include the fact that these results only represent distances from 50 m to 200 m and from a group of selected Swiss elite swimmers. However, the finding that the sex difference among the fastest three swimmers between 2006 and 2010 was highest in the 50 m and lowest in 200 m can be confirmed with data collected on swimmers competing at the international level (finalists in the FINA World Championship) in the same time frame for freestyle, although not for butterfly (Fig. 6). The sex differences in the 50 m, 100 m and 200 m freestyle were 11.3% ± 0.1, 10.5% ± 0.5 and 10.0% ± 0.3, respectively. In butterfly, however, the sex differences were 10.9% ± 0.3, 11.2% ± 0.1 and 9.4% ± 0.4, respectively. As butterfly events are normally held over 50 m to 200 m, comparisons between butterfly and freestyle swimming are somewhat limited in this regard. Furthermore, other



p values indicate distances and disciplines significantly different from each other

Figure 6. Sex difference between the three fastest men and women at the international level (FINA World Championship finalists) between 2006 and 2010 for discipline and distance

variables such as physiological parameters [36], anthropometric characteristics [14], training data [37], previous experience [38], nutrition [39, 40] and motivational [41] factors of the swimmers were not considered. These variables may have had an influence on race outcomes. Future studies ought to investigate the trend of decreasing sex difference of swimming speed by analysing increasing distance intervals above 400 m to 1500 m in 5 km, 10 km or 25 km competitions. Additionally, analysis should include elite swimmers competing at the world class level such as World Championships or Olympic Games.

Conclusions

Women achieved peak swimming speed at the age of 20–21 years for the 50 m, 100 m and 200 m in both butterfly and freestyle. Men achieved their fastest swimming speed in the 50 m butterfly at the age of 20–21 years and at 18–19 years for the 100 m and 200 m, whereas in freestyle at 26–27 years in the 50 m and 22–23 years in the 100 m and 200 m. The sex difference in swimming speed decreased with increasing race distance for both the butterfly (from 14.1% ± 0.2 in the 50 m to 8.7% ± 1.8 in the 200 m) and freestyle (from 16.2% ± 0.5 in the 50 m to 14.9% ± 1.0 in the 200 m). The causes behind the decrease in sex difference for swimming speed in both the butterfly and freestyle with increasing race distance and why the sex difference in swimming performance was lower in the butterfly than in freestyle swimming require further investigation. Furthermore, future studies should include analysis of anthropometric and physiological characteristics between butterfly and freestyle swimmers and also improve statistical analyses by using non-linear regression analyses.

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