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THE EFFECT OF COURSE LENGTH ON BUTTERFLY SWIMMING PERFORMANCE IN NATIONAL AND INTERNATIONAL SWIMMERS

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Abstract

Introduction: Effects of course length and recent advances on performance in butterfly swimming have not been previously investigated.

Objective: The aims to this study were (*i*) to compare the butterfly swim performance on short (25m) *versus* long (50m) courses and (*ii*) to examine the changes in butterfly swimming speed during the 2000–2011 period for both female and male national (Switzerland) and international competitors (FINA World Championship finalists).

Methods: Swimming speeds were analysed for 45,583 Swiss swimmers and for 573 FINA finalists, competing in 50m, 100m, and 200m races. Analysis of variance (ANOVA) was used to compare swimming speeds for different groups and linear regression was used to assess temporal trends.

Results: Swimming speeds of swimmers at national and international level were on average 1.3±0.7% faster on short courses than on long courses for both sexes and all race distances. Sex-related differences in swimming speed were greater on short courses than on long courses for athletes at international level ($P < 0.01$). Sex-related differences for swimmers at national level were greater on long courses, but only for 200m races ($P < 0.01$). Performance of athletes at international level improved on both short and long courses ($r^2 = 0.58–0.88$, $P < 0.05$), while swimmers at national level showed a consistent improvement only in long-course events ($r^2 = 0.37–0.74$, $P < 0.05$). In short-course events, women at national level improved in 50m and 100m, while men at national level improved only in 100m ($r^2 = 0.37–0.56$, $P < 0.05$).

Conclusion: To summarize, (*i*) swimmers at both national and international level were ~1.3% faster on short courses compared to long courses for both sexes and all distances and (*ii*) performance of athletes at international level improved on both short and long courses while athletes at national level improved only on 100m for both sexes.

Key words: *swim speed, pool length, sex-related difference, temporal trends*

Introduction

Swimming competitions are held on both short (25m) and long (50m) courses [1]. It is widely accepted that swimming speeds over comparable distances were generally faster for short-course than for long-course events [2], largely due to the greater number of turns, which provide increased propulsion and moderate exercise recuperation [3-5]. The higher numbers of turns provide several physiological and biomechanical advantages on short courses, such as a lower heart rate and lower blood lactate levels as has been shown in freestyle swimming events [4,6,7]. While effects of course length have been studied for freestyle swimming, no previous study investigated the effects on butterfly swimming and extrapolation from freestyle to butterfly is problematic because each stroke has its own physical requirements and physiology [8,9].

The effects of course length on swimming speed seemed to differ between men and women. Male freestyle swimmers gained more advantage in short-course events than women because men were able to reach higher swimming speeds during turns [10]. However, differential effects of course length on men and women have only been analysed for 50m freestyle events where previous studies of sex-related differences in swimming speed for other swim styles only used results of long-course events [10]. The competition level, *e.g.*, national *versus* international events, might also influence the effects of course length, especially in butterfly swimming requiring advanced technical skills [11].

Freestyle swimming performance during the last decade was influenced by the introduction and prohibition of new technologies, resulting in significant temporal changes in swimming speed [12-14]. However, new records in freestyle and butterfly swimming set at short- and long-course events by both men and women during the 2012 Olympic Games and the 2012 FINA World Championships [2] suggested that swimming performance was still improving.

The present study examined (*i*) the effects of course length on butterfly swimming speed and (*ii*) the changes in butterfly swimming sped for both men and women at national level (Switzerland) and international level (finalists at FINA World championships) during the 2000-2011 period. We hypothesized that (*i*) swimming speed in butterfly would be faster on short than on long courses for both sexes, and (*ii*) butterfly swimming speed would improve over time in both short- and long-course events.

Methods

The study was approved by the Institutional Review Board of St. Gallen, Switzerland. The requirement for informed consent was waived on the basis that the study involved the analysis of publicly available data.

Data sampling and data analysis

Performance in 50m, 100m, and 200m butterfly races was analysed for all athletes on the Swiss high score list and for FINA World Championship finalists during 2000-2011. The data were obtained for swimmers at national level from the Swiss Swimming Federation (http://rankings.fsn.ch/) and for swimmers at international level from the Fédération Internationale de Natation (http://www.fina.org).

For short-course events, data were available for 23,272 Swiss athletes (*i.e.* 11,523 women and 11,749 men), and for 185 FINA athletes (*i.e.* 144 women and 141 men). For long-course events, data were available for 22,311 Swiss athletes (*i.e.* 10,976 women and 11,335 men), and 188 FINA athletes (*i.e.* 144 women and 141 men).

Retrieved swimming times were converted to swimming speed prior to analyses using the equation [swimming speed in m/s] = [race distance in m] / [race time in s]. To examine temporal trends in swimming speed and effects of course length for swimmers at national level, the swimming speeds for male and female top ten athletes were identified for races on long and short courses, for each race distance and year. The same analyses were performed for swimmers at international level, using the top eight swimming speeds for male and female athletes. However, the FINA World Championships were not held annually.

The top ten swimming speeds for all twelve years were pooled (*i.e.* 120 swimming speeds for each distance and course length) to examine the interactive effect of sex and course length on performance in swimmers at both national and international level. Sex-related differences in swimming speed were calculated as the absolute value of ([swimming speed in women] – [swimming speed in men]) / [swimming speed in men] × 100. The sex-related difference was calculated for pairs of equally placed athletes (e.g., 1st place woman and man, 2nd place woman and man, etc.), and the mean sex-related difference (±SD) was calculated using the paired data.

Statistical Analysis

Prior to statistical analyses, each set of data was tested for normal distribution and homogeneity of variances. Normal distribution was tested using the D'Agostino and Pearson omnibus normality test; homogeneity of variances was tested using Levene's test in case of two groups, and Bartlett's test in case of more than two groups. Student's *t*-test was used to determine the significance of differences between two groups. A one-way analysis of variance (ANOVA) with subsequent Dunnett post-hoc analysis was used to determine the significance of differences between more than two groups. A two-way ANOVA was used to determine the significance of the interactive effect of sex and course length on performance. Linear regression analysis was used to determine the significance of temporal changes in a variable. Statistical analyses were performed using IBM SPSS Statistics (Version 19, IBM SPSS, Chicago, IL, USA) and GraphPad Prism (Version 5, GraphPad Software, La Jolla, CA, USA). Significance was accepted at $P < 0.05$ (two-tailed for *t*-tests). Data reported in the text and figures are mean ± standard deviation (SD).

Results

Effects of course length on swimming speed and sex--related differences

Swimming speeds of men and women competing in butterfly were on average 1.3±0.7% faster on short- than on long-course events. At international level in the FINA World Championships, swimming speed were significantly faster on short courses than on long courses for 50m, 100m, and 200m distances (Fig. 1, Tables 1 and 2). Athletes at national elvel achieved significantly faster swimming speeds in short-course than in long-course events, with the exception of women competing in 200m races with no significantly different swimming speeds on short and long courses (Fig. 2, Tables 1 and 2).

Men were consistently faster than women for all distances and course lengths (Fig. 1 and 2, Table 2). The sex-related difference in both short- and long-course events decreased significantly with increasing race distance (*i.e.* athletes at international level: 50m vs. 200m, 11.0±0.3% *versus* 9.8±0.4% on short-courses, and 10.6 ± 0.3% *versus* 9.1 ± 0.3% on long courses; *t*-test, $P < 0.05$ for both and athletes at national level: 50m *vs.* 200m races, 12.3 ± 0.4 vs. 10.4 ± 1.7% on short courses, and 12.4 ± 0.2 vs. 10.1 ± 2.0% on long courses; *t*-test, $P < 0.05$ for both). For athletes at international level, the sex-related difference was significantly greater in short-course than in long-course events at 50m and 200m distances (Fig. 1), but did not vary with course

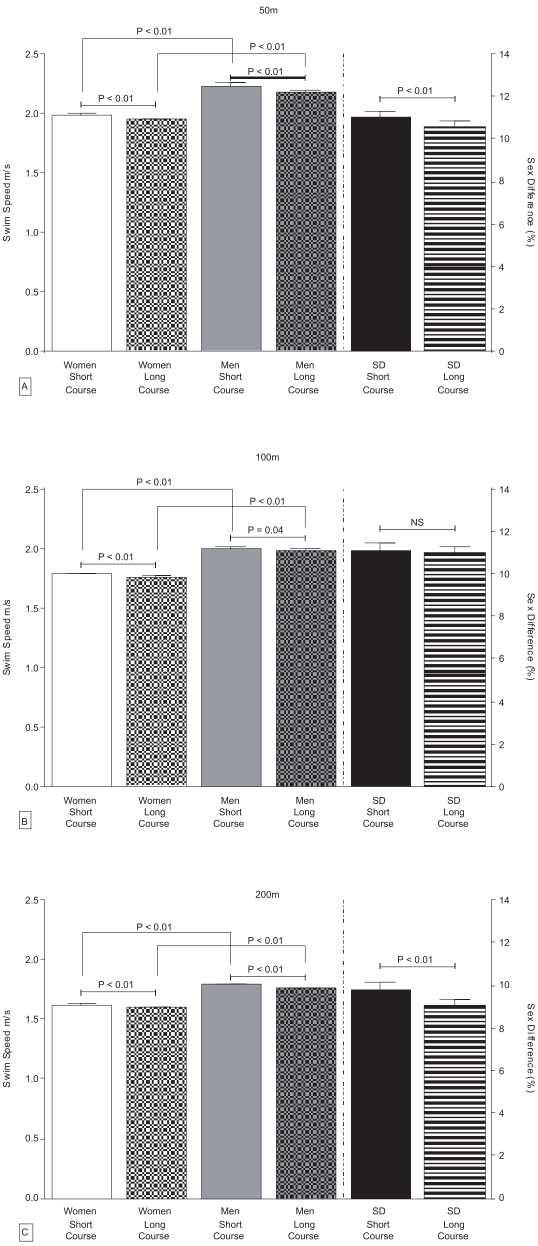

Fig. 1. *Swimming speed and sex-related difference of the FINA World Champion finalists overall top ten male and female butterfly swimmers from 2000 to 2011 over 50m to 200m distances. The P -value is inserted in case of a significant difference between short-course and long-course swimming. 'NS' indicates absence of a significant difference.*

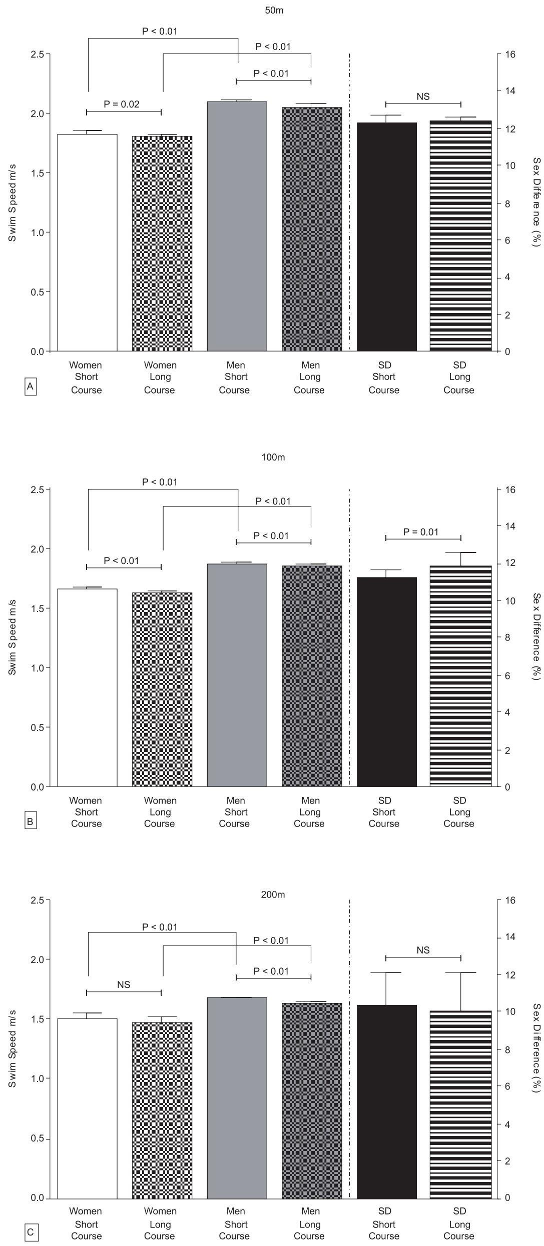

Fig. 2. *Swimming speed and sex-related difference of the Swiss overall top ten male and female butterfly swimmers from 2000 to 2011 over 50m to 200m distances. The P -value is inserted in case of a significant difference between short-course and long-course swimming. 'NS' indicates absence of a significant difference.*

Table 1. *Percent difference (%) in swimming speeds in swimmers at international and national level on short (25m) and long (50m) courses during the 2000-2011 period*

	Percent difference (mean ±SD)			
	50m	100m	200m	ANOVA
Men				
International	2.14 ± 1.00	1.53 ± 1.19	1.58 ± 0.61	$P < 0.0001$
National	0.56 ± 1.56	1.81 ± 1.02	2.50 ± 1.28	$P < 0.0001$
Women				
International	1.07 ± 1.00	0.85 ± 0.95	0.56 ± 1.13	$P = 0.003$
National	0.03 ± 1.62	1.20 ± 1.49	1.69 ± 1.82	$P < 0.0001$

Table 2 *Statistical significance (2-way ANOVA) of effects of sex and course length, and the interactive effects of sex × course length on speed of butterfly swimmers at national and international level*

	Results of 2-way ANOVA		
	sex	course length	sex × course length
National level			
50m	F = 3513.7, *P* < 0.0001	F = 1.5, *P* = 0.23	F = 1.5, *P* = 0.23
100m	F = 3796.9, *P* < 0.0001	F = 46.9, *P* < 0.0001	F = 1.9, *P* = 0.18
200m	F = 2882.1, *P* < 0.0001	F = 103.2, *P* < 0.0001	F = 2.1, *P* = 0.15
International level			
50m	F = 2722.2, *P* < 0.0001	F = 50.6, *P* < 0.0001	F = 7.5, *P* = 0.007
100m	F = 3650.9, *P* < 0.0001	F = 36.0, *P* < 0.0001	F = 3.3, *P* = 0.071
200m	F = 4131.5, *P* < 0.0001	F = 49.3, *P* < 0.0001	F = 16.5, *P* < 0.0001

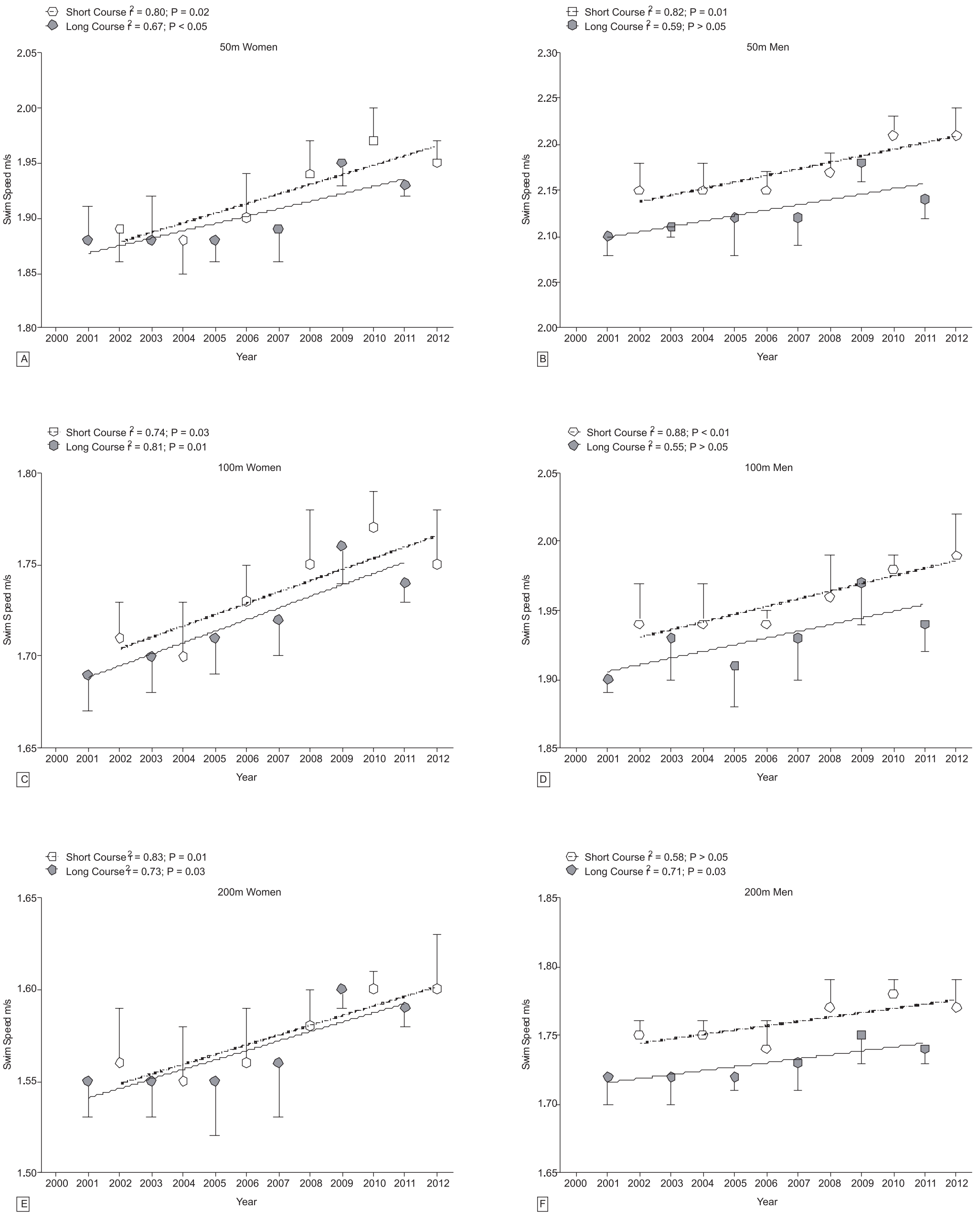

Fig. 3. *Changes in swimming speed of top eight female and male butterfly FINA World Champion finalists during each edition from 2000 to 2011 in short--course vs. long-course events from 50m to 200m. (Mean ± SD)*

Table 3 *r^2, P and slopes of linear regressions shown in Figures 3 and 4*

	National level						International level					
	Short course			Long course			Short course			Long course		
	r^2	*P*	slope x 10^{-2}	r^2	*P*	slope x 10^{-2}	r^2	*P*	slope x 10^{-2}	r^2	*P*	slope x 10^{-2}
Men												
50m	0.23	0.12	0.48	0.56	0.006	0.49	0.82	0.012	0.71	0.59	0.075	0.59
100m	0.56	0.005	0.49	0.74	0.0003	0.55	0.88	0.006	0.56	0.55	0.091	0.49
200m	0.15	0.21	0.20	0.37	0.035	0.20	0.58	0.080	0.31	0.71	0.034	0.29
Women												
50m	0.37	0.035	0.60	0.62	0.002	0.53	0.80	0.017	0.87	0.67	0.045	0.67
100m	0.46	0.015	0.54	0.64	0.002	0.49	0.74	0.027	0.61	0.81	0.014	0.63
200m	0.15	0.22	0.21	0.06	0.45	0.06	0.83	0.011	0.53	0.73	0.030	0.51
Sex-related difference												
50m	0.08	0.37	-9.02	0.06	0.46	-4.97	0.31	0.25	-7.49	0.33	0.23	-8.80
100m	0.04	0.54	-5.87	0.00	0.93	0.49	0.01	0.83	-2.40	0.68	0.043	-11.89
200m	0.01	0.76	-3.15	0.12	0.28	6.33	0.78	0.020	-14.99	0.55	0.090	-12.33

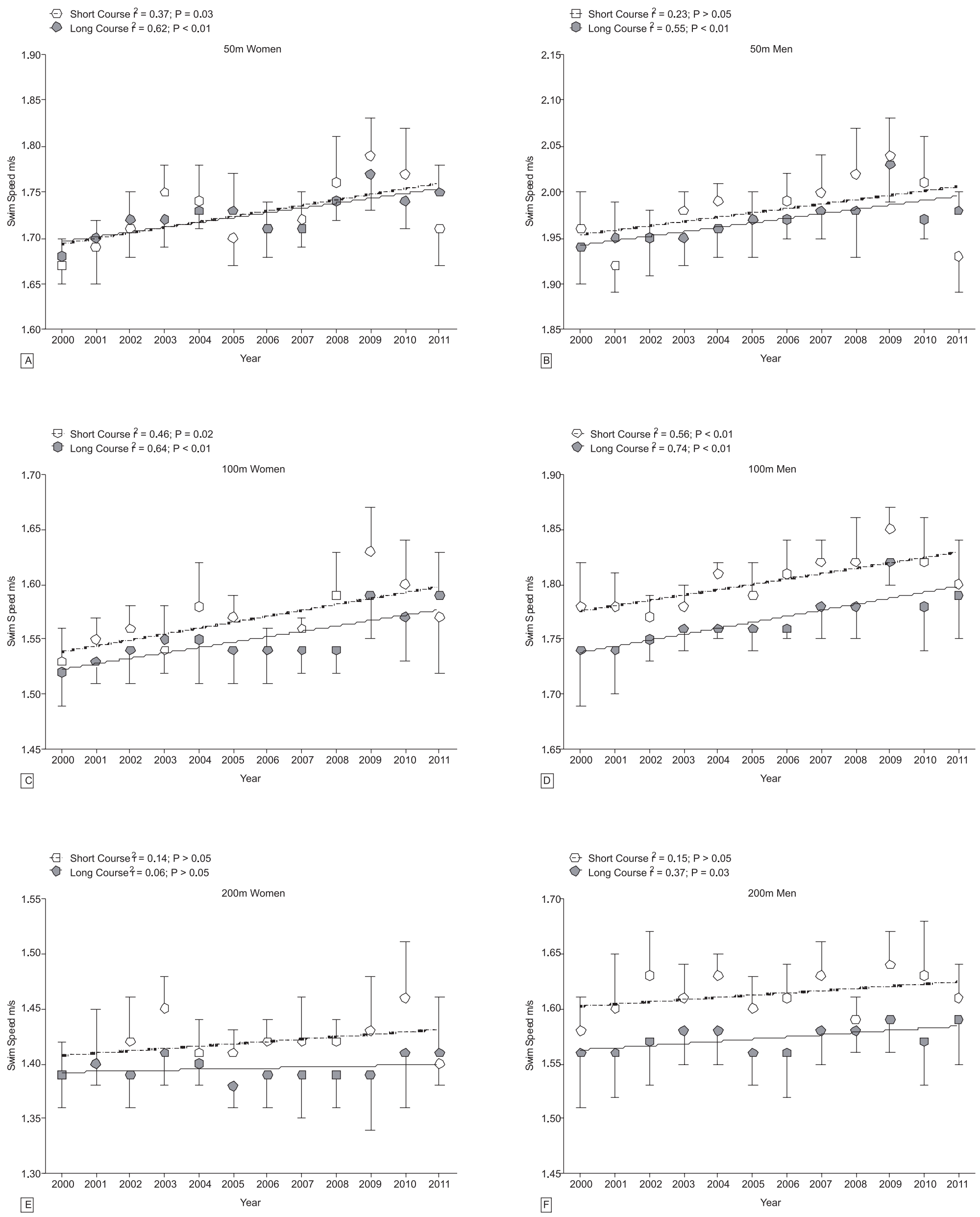

Fig. 4. *Changes in swimming speed of top ten Swiss female and male butterfly swimmers from 2000 to 2011 in short-course vs. long-course events from 50m to 200m. (Mean ± SD)*

length in 100m races. For athletes at national level, the sex-related difference was significantly smaller in short-course than in long-course events of 100m, but did not vary with course length in 50m or 100m races (Fig. 2). The interactive effect of sex and course length was only significant for swimmers at international level competing in 50m and 200m races (Table 2).

Temporal changes in swimming speed and sex-related differences

Swimming speeds of women at international level in both long- and short-course events increased significantly from 2000 to 2011 (Fig. 3, Table 3). Swimming speeds of men at international level improved significantly in short-course events of 50m and 100m, and improved, although not significantly, in 200m races. In long-course events, men at international level improved at all distances, but only significantly in 200m races. Swimming speeds of men and women at national level improved significantly over time in all long-course events, except for the women's 200m (Fig. 4, Table 3). In short-course events, both sexes improved significantly their swimming performance over time in 100m races, and women improved in 50m races.

Swimming speeds of women at international level improved to a larger extent than swimming speeds of men, so that sex-related differences decreased significantly over time in 100m and 200m long-course events, and in 100m short-course events (Table 3). Sex-related differences in performance for swimmers at national level did not change significantly over time.

Discussion

The present study had several noteworthy results. Firstly, elite swimmers at international and national level competing in 50m, 100m, and 200m butterfly were faster on short (25m) courses than on long (50m) courses (*i.e.* on average 1.3±0.7%). Secondly, the sex-related difference in swimming speed decreased with increasing swimming distance in both short- and long-course events. Thirdly, swimming speeds of both male and female swimmers at international level increased significantly during the 2000-2011 period, for all distances on long and short courses. Swimming speeds of athletes at national level also improved in long-course events, but only women at national level improved in short-course events, and only for 50m and 100m distances.

Interpretation of these results is limited to some extent by the observational and cross-sectional study design. We could not assess direct influences of anthropometric [15-17], biomechanical [6,16] or physiological [16] factors. However, this lack is compensated by the very large study population, which provided sufficient power to detect small but statistically significant differences between groups.

Effects of course length on swimming speed and sex-related differences

Results of the present study supported the hypothesis that swimming speeds in butterfly would be faster on short courses than on long courses, irrespective of sex and race distance, confirming previous results on freestyle swimming [6,7]. Swimmers competing in 200m freestyle events spend about twice as much time turning and gliding in 25m pools as in 50m pools (*i.e.* 31.5 s *versus* 13.5 s, on average, [6]. Each turn offers recovery time, resulting in a decreased lactate production and an increased lactate clearance in the upper body and arm muscles used for regular stroking [4,6,7,10,18]. Faster swimming speeds of international top swimmers in butterfly competitions were partly attributed to better turning skills compared to their counterparts at the national level [11].

In freestyle swimming, male swimmers gain more advantage from turning than female swimmers, leading to a greater sex-related difference in swimming speed on short courses [10]. Swimmers at international level in butterfly competitions exhibited the same effect of course length on sex-related differences, possibly explained by the significantly greater peak leg power in men than in women [19], which could be particularly effective in short-course events [20]. However, swimmers at national level showed not the expected effect of course-length on sex-related differences in swimming performance, suggesting that elite men competing in butterfly at national level might be less skilled and/or less powerful compared to international competitors. Technique, which is particularly important in butterfly swimming, was found to be less well developed in national than in international competitors [11].

The decrease in sex-related differences with increasing race distance, for athletes at both national and international level irrespective of course length, is in agreement with observations on freestyle and individual medley swimming [21,22]. The decrease is attributable to higher economy of female swimmers, which becomes more important as race distance increases. The smaller body size, the lower body drag, the higher body fat percentage, the lower body density, and the shorter lower limbs of women result in more horizontal and streamlined swim positions, and greater swimming economy compared to men [23-26]. The greater muscle power of men, furthermore, becomes less important as race distance increases, leading to a smaller gender gap in performance [27].

Changes in swimming speed and sex-related differences from 2000 to 2011

The hypothesis that butterfly performance would improve over time was supported by changes in swimming speeds in swimmers at international level in both long- and short-course events, and of swimmers at national level in long-course events. This improvement is not surprising, considering recent records in both long- and short-course events set at the 2012 Olympic Games and the FINA World Championships [2]. Elite American swimmers also exhibited recent improvement in butterfly performance in 100m long-course events [13].

Changes in performance are influenced by technological advances [28], changes in anthropometric [29] and physiological factors [16], psychological [30] and nutritional aspects [31], as well as improved techniques and/or training protocols [32]. Recent improvements in butterfly swimming performance are probably related to technological advances, such as deeper, deck-level pools, more effective anti-wave lane ropes, and improved swim suits [12,33]. Full body swim suits alone were responsible for an unprecedented run of broken records during the last decade [14,33-35]. FINA regulated the use of the new swim suits in 2010, but this was compensated for by the introduction of other technologies, such as new starting blocks with extended platforms and greater angles [12,36,37].

In addition to technological advances, improved swimming techniques and/or training methods, and increased access to the sport by a larger number of athletes [38,39] probably contributed to the observed improvements in butterfly performance. The lack of significant improvement in swimmers at national level in short-course events might be due to lesser use of new technologies or less intense training, leading to lower technical skills [11,40,41], which are particularly important in butterfly competitions on short courses. Psychology and motivation, which also affect athletic performance, might also differ between national and international-level competitors [13,42].

As women at international level improved their swimming speeds to a larger extent than men at international level, the sex-related differences declined significantly, especially in 100m and 200m races. However, sex-related differences for swimmers at national level were stable over time, consistent with long-term stability of sex-related differences in freestyle swimming [14,38,43]. The factors that determine sex-related differences, such as body dimensions, buoyancy, stroke mechanics, anaerobic power and capacity, muscle power, flexibility, start and turn times, and basic and specific endurance, are unlikely to change significantly during an 11-year period [22,43,44]. A possible explanation for the decrease in the sex-related difference in butterfly swimmers at international level might be increasing access and more intense training of women competing at the international level.

Conclusions

For the first time our data provide extensive evidence over the complete range of official butterfly race distances that pool length plays a tremendous role in determining butterfly swimming performance. Elite butterfly swimmers at both national and international level were ~1.3% faster on short (25m) than on long (50m) courses from 50m to 200m. During the 2000-2011 period, performance of swimmers at international level improved in both long- and short-course races, while swimmers at national level improved in long-course events, suggesting that butterfly swimming has further potential for improvement, especially in competitions at national level. The narrowing sex-related difference in competitions at international level warrants further investigation to identify differential factors. Additional investigations of competitive swimming, including effects of anthropometric, biomechanical, and physiological factors, are required to fully understand the effects of course length on swim performance. Training programs for short course events should aim in particular at improving turning skills, as this race component is highly associated with better butterfly performance.

Competing interests

The authors declare that they have no competing interests.

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