Differences in swimming speed on short course and long course for female and male breaststroke swimmers: a comparison of swimmers at national and international level

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Abstract
Introduction
The aims were to examine (i) the difference in swimming speed in breaststroke swimmers between short and long course and (ii) the change in swimming speed across years for elite female and male swimmers competing at national and international level.

Materials and methods
Swimming speed of breaststroke swimmers at national level (i.e., athletes listed in Swiss swimming high score list between 2000 and 2011) and at international level (i.e., finalists of World Championships between 2001 and 2012) were analysed for three course distances (i.e., 50 m, 100 m and 200 m) using linear regression analyses and analysis of variance.

Results
Swimming speed was faster in short course than in long course in 50 m (1.8–2.6%), 100 m (2.2–3.6%) and 200 m (2.6–4.2%), respectively. Swimming speed increased between 1.2 and 5.2% both for short course and long course across years, independently of the sex and the distance. For all distances, the sex difference was greater in long course than in short course. Mean values for the sex difference in swimming speed at national level were 12.1% in short course versus 11.9% in long course for 50 m, 11.9% in short course versus 11.3% in long course for 100 m and 11.0% in short course versus 10.7% in long course for 200 m, with significant difference only for 200 m long course (p = 0.03). Mean values for sex difference in swimming speed at international level were 13.3% in short course versus 12.7% in long course for 50 m, 12.6% in short course versus 11.9% in long course for 100 m and 12.1% in short course versus 11.2% in long course for 200 m, only with significance for 100 m short course (p = 0.01).

Conclusion
Elite breaststroke swimmers were ~3% faster on short course compared to long course. The sex difference in breaststroke swimming speed from 50 m to 200 m events was ~11% (with significance at national level on 200 m long course and on international level on 100 m short course) but appeared slightly greater in long course compared to short course.

Introduction
Indoor swimming competitions are usually held in short course (25 m) and long course (50 m) pools. Blanksby reported that swimming world records were faster in 25 m pools due to the higher number of turns and push offs. The higher number of turns and push offs leads to a redistribution of muscular load, reduced blood lactates and physiological recuperation can occur during the turn. With increasing race distance, swimmers perform more turns on long course than on short course.

Breast stroke is a swim style with a discontinuous technique like the butterfly. The variation in velocity in breast stroke and butterfly were twice as large as in freestyle swimming. Butterfly presented higher velocity than breast stroke and back stroke. The stroke frequency is also higher than in breast stroke and the stroke length is higher than in the crawl. High intra-cyclic variation in the average impulse can be found in butterfly and breast stroke which results from the large acceleration and deceleration phases within the stroke cycle. Energetic cost is greater in the butterfly, followed by breast stroke, back stroke and freestyle.

Breast stroke turns can account to one third of race time in 25 m pools in all 200 m events and longer. Thereby, the oxygen costs through the acceleration are considerable. In breast stroke swimming, velocity increases by increasing stroke frequency and decreasing distance per stroke. Summarising biomechanical factors such as stroking parameters characterise swimming speed improvements best followed by physical factors like body height and arm-span and physiological factors like peak oxygen consumption.

To the best of our knowledge, there were no other studies focusing on (i) the change in swimming speed across years and (ii) the difference in swimming speed between long course and short course only for a single discipline like breaststroke. Therefore, the aims of this study were to examine (i) the difference in swimming speed between short and long course for breaststroke and (ii) the change in swimming speed in breast stroke swimming across years.

To achieve these aims, we compared the swimming speeds of elite breaststroke swimmers at national level from the Swiss swimming high score list between 2000 and 2011 and
at international level from the finals of the FINA World Championships between 2001 and 2012. The advantage of the Swiss data was that they were recorded annually. Data from the world championships were, however, only every 2 years available.

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

Data sampling and data analysis
The data set from this study was obtained for national swimmers from the Swiss Swimming Federation and for international swimmers from the European Swimming Federation for breaststroke swimmers at national level (i.e., athletes ranked in the Swiss swimming high score list between 2000 and 2011) and breaststroke swimmers at international level (i.e., finalists from the FINA World Championships between 2001 and 2012) were included. We compared the change in breaststroke swimming speed across years and the difference in breaststroke swimming speed between long course and short course.

The annual top 10 (i.e., 10 fastest swimming times) men and women for the three race distances (i.e., 50 m, 100 m, 200 m) were determined for long course and short course and analysed regarding the change in swimming speed and sex difference over time. The annual top 10 athletes per sex, distance and course length were pooled (i.e., 12 years × 10 athletes = n = 120 per distance and course length) and analysed regarding the interaction between sex and course length on swimming speed. In order to increase the comparability of the results with similar studies, all race times were converted to swimming speed prior to analysis. Swimming speed was calculated using the equation [swimming speed in m/s] = [race distance in m] / [race time in seconds]. The sex difference in performance was calculated using the equation ([swimming speed in women] – [swimming speed in men]) / [swimming speed in men] × 100, where sex difference was calculated for every pairing of equally placed athletes (e.g., between men and women 1st place, between men and women 2nd place, etc.) before calculating mean value and standard deviation of all the pairings. In order to facilitate reading all sex differences were transformed to absolute values prior to analyses. To compare top swimming speed between long course and short course swimmers, the overall top 10 (i.e., 10 fastest swimming speed) female and male swimmers from the Swiss swimming high score list between 2000 and 2011 and the eight finalists from the FINA World were determined for long course and for short course swimming and compared regarding swimming speed and sex difference.

Statistical analysis
In order to increase the reliability of the data analyses, each set of data was tested for normal distribution as well as for homogeneity of variances prior to statistical analyses. Normal distribution was tested using a D’Agostino and Pearson omnibus normality test and homogeneity of variances was tested using a Levene’s test in case of two groups and with a Bartlett’s test in case of more than two groups. Linear regression was used to find significant changes in a variable across years. A Student’s t-test with Welch’s correction in case of unequal variances was used to find significant differences between two groups. A one-way analysis of variance (ANOVA) with subsequent Dunnett post-hoc analysis was performed to find significant differences between more than two groups (i.e., the fastest age group and the other age groups). A two-way-ANOVA (sex × course length) was performed to determine the interaction between sex and course length on swimming speed. 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-sided for t-tests). Data in the text are given as mean ± standard deviation.

Results
Data from the Swiss swimming high score list were available from 26,556 athletes, including 13,277 women and 13,279 men on short course and from 25,111 athletes, including 12,627 women and 12,484 men on long course. Data from 125 finalists from the FINA World Championships were available, including 56 women and 69 men on short course and from 112 athletes, including 54 women and 58 men on long course.

Comparison of swimming speed in breaststroke between short and long courses
Swimming speed was faster on short than on long course for 50 m, 100 m and 200 m for both courses. Differences in swimming speed between 25 m and 50 m pools for the elite Swiss swimmers were 2.7% ± 0.9 [range: 1.8–3.6%] (Table 1). The mean differences in swimming between 25 m and 50 m pools at the FINA World Championships were 3% ± 1.15 [range: 1.9–4.2%] (Table 2).

Change in breaststroke swimming speed across the years
Breaststroke swimming speed increased for both short and long courses over the years independent of sex and race distance for both courses. Male Swiss swimmers improved swimming speed significantly by 1.2% (p = 0.04) on the 50 m short
course and 2.63% \( (p = 0.03) \) on the 100 m short course. Female Swiss swimmers improved swimming speed significantly by 2.78% \( (p = 0.004) \) on the 50 m long course, by 3.03% \( (p = 0.01) \) on the 100 m long course and by 4.09% \( (p = 0.04) \) on the 200 m long course. Male Swiss swimmers showed a significant improvement of 2.44% \( (p = 0.0003) \) on the 50 m long course, 3.36% \( (p = 0.01) \) on the 100 m long course and 5.15% \( (p = 0.003) \) on the 200 m long course, respectively (Figure 1 and Table 3).

The mean improvement of the two distances for men on the short course was 1.9 ± 0.7% and of the three distances for the long course 3.6 ± 1.1%. The mean improvement of the three distances for women on the long course was 3.3 ± 0.6%.

Figure 2 and Table 4 show the same trend for the FINA World Championships. Female swimmers at international level improved swimming speed significantly by 2.4% \( (p = 0.0183) \) on the 50 m short course, by 3.4% \( (p = 0.0023) \) on the 100 m short course and by 2.8% \( (p = 0.0138) \) on the 200 m short course, respectively. Male swimmers showed a significant improvement by 2.7% \( (p = 0.0168) \) on the 50 m short course, by 2.9% \( (p = 0.0023) \) on the 100 m short course and by 3.8% \( (p = 0.01) \) on the 200 m short course, respectively. Women achieved a significant improvement of 2.5% \( (p = 0.02) \) on the 50 m long course and 2.7% \( (p = 0.03) \) on the 100 m long course.

The mean improvement in three distances for men on the short course was 3.19 ± 0.5%. The mean improvement of the three distances for women on the short course was 2.9 ± 0.5%. Women showed a mean improvement of 2.6 ± 0.1% on the long course during the studied period.

Table 1 Mean swim speed of the annual top 10 women and men Swiss athletes in breaststroke swimming in 50 m, 100 m and 200 m in short course and long course

<table>
<thead>
<tr>
<th>Distance and sex</th>
<th>Short course (m/s)</th>
<th>Long course (m/s)</th>
<th>Absolute difference (m/s)</th>
<th>Difference in percent (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>50 m women</td>
<td>1.49 ± 0.03</td>
<td>1.46 ± 0.02</td>
<td>0.03</td>
<td>1.8</td>
</tr>
<tr>
<td>50 m men</td>
<td>1.69 ± 0.03</td>
<td>1.66 ± 0.02</td>
<td>0.03</td>
<td>2.0</td>
</tr>
<tr>
<td>100 m women</td>
<td>1.38 ± 0.02</td>
<td>1.34 ± 0.02</td>
<td>0.04</td>
<td>2.9</td>
</tr>
<tr>
<td>100 m men</td>
<td>1.56 ± 0.03</td>
<td>1.51 ± 0.02</td>
<td>0.06</td>
<td>3.6</td>
</tr>
<tr>
<td>200 m women</td>
<td>1.28 ± 0.02</td>
<td>1.24 ± 0.02</td>
<td>0.04</td>
<td>2.8</td>
</tr>
<tr>
<td>200 m men</td>
<td>1.43 ± 0.03</td>
<td>1.39 ± 0.02</td>
<td>0.05</td>
<td>3.2</td>
</tr>
</tbody>
</table>

Table 2 Mean swimming speed of the top eight women and men in World Championship in breaststroke swimming in 50 m, 100 m and 200 m in short course and long course

<table>
<thead>
<tr>
<th>Distance and sex</th>
<th>Short course (m/s)</th>
<th>Long course (m/s)</th>
<th>Absolute difference (m/s)</th>
<th>Difference in percent (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>50 m women</td>
<td>1.68 ± 0.01</td>
<td>1.65 ± 0.01</td>
<td>0.03</td>
<td>1.9</td>
</tr>
<tr>
<td>50 m men</td>
<td>1.90 ± 0.01</td>
<td>1.85 ± 0.01</td>
<td>0.05</td>
<td>2.6</td>
</tr>
<tr>
<td>100 m women</td>
<td>1.55 ± 0.01</td>
<td>1.52 ± 0.01</td>
<td>0.03</td>
<td>2.2</td>
</tr>
<tr>
<td>100 m men</td>
<td>1.74 ± 0.01</td>
<td>1.70 ± 0.01</td>
<td>0.05</td>
<td>2.7</td>
</tr>
<tr>
<td>200 m women</td>
<td>1.45 ± 0.02</td>
<td>1.41 ± 0.00</td>
<td>0.04</td>
<td>2.6</td>
</tr>
<tr>
<td>200 m men</td>
<td>1.62 ± 0.01</td>
<td>1.56 ± 0.01</td>
<td>0.07</td>
<td>4.2</td>
</tr>
</tbody>
</table>

Table 3 Change in swimming speed of the annual top ten women and men at national level in breaststroke swimming in 50 m, 100 m and 200 m in short course and long course

<table>
<thead>
<tr>
<th>Distance and sex</th>
<th>Short course increase absolute (m/s)</th>
<th>Long course increase absolute (m/s)</th>
<th>Short course increase relative (%)</th>
<th>Long course increase relative (%)</th>
<th>Significance, p</th>
</tr>
</thead>
<tbody>
<tr>
<td>50 m women</td>
<td>0.04</td>
<td>2.78 ± 0.57</td>
<td>0.04</td>
<td>0.0048</td>
<td></td>
</tr>
<tr>
<td>50 m men</td>
<td>0.02</td>
<td>2.44 ± 1.13</td>
<td>0.04</td>
<td>0.0003</td>
<td></td>
</tr>
<tr>
<td>100 m women</td>
<td>0.04</td>
<td>3.03 ± 0.57</td>
<td>0.05</td>
<td>0.0113</td>
<td></td>
</tr>
<tr>
<td>100 m men</td>
<td>0.04</td>
<td>3.36 ± 1.13</td>
<td>0.05</td>
<td>0.0132</td>
<td></td>
</tr>
<tr>
<td>200 m women</td>
<td>0.05</td>
<td>4.09–0.57</td>
<td>0.05</td>
<td>0.0417</td>
<td></td>
</tr>
<tr>
<td>200 m men</td>
<td>0.07</td>
<td>5.15–1.13</td>
<td>0.07</td>
<td>0.0038</td>
<td></td>
</tr>
</tbody>
</table>

The missing data were not included because they were not significant.
A Short Course $r^2 = 0.29; P > 0.05$
Long Course $r^2 = 0.57; P < 0.01$

50m Women

B Short Course $r^2 = 0.33; P < 0.05$
Long Course $r^2 = 0.75; P < 0.01$

50m Men

C Short Course $r^2 = 0.25; P > 0.05$
Long Course $r^2 = 0.49; P = 0.01$

100m Women

D Short Course $r^2 = 0.39; P = 0.03$
Long Course $r^2 = 0.47; P = 0.01$

100m Men

E Short Course $r^2 = 0.13; P > 0.05$
Long Course $r^2 = 0.35; P = 0.04$

200m Women

F Short Course $r^2 = 0.17; P > 0.05$
Long Course $r^2 = 0.58; P < 0.01$

200m Men

Figure 1: Swimming speed of the annual top 10 women (Panels A, C, E) and top 10 men (Panels B, D, F) competing at national level in breaststroke swimming in 50 m (Panels A, B), 100 m (Panels C, D) and 200 m (Panels E, F) in short course and long course.

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Table 4  Change in swimming speed of the top eight women and men athletes between 2001 and 2012 (World Championship, took place alternately on short course and long course) in breaststroke swimming in 50 m, 100 m and 200 m in short course and long course

<table>
<thead>
<tr>
<th>Distance and sex</th>
<th>Short course increase absolute</th>
<th>Long course increase absolute</th>
<th>Short course increase relative</th>
<th>Long course increase relative</th>
<th>Significance, p</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(m/s)</td>
<td>(m/s)</td>
<td>%</td>
<td>%</td>
<td>Short course</td>
</tr>
<tr>
<td>50 m women</td>
<td>0.04</td>
<td>0.04</td>
<td>2.45 ± 0.46</td>
<td>2.53 ± 0.1</td>
<td>0.0183</td>
</tr>
<tr>
<td>50 m men</td>
<td>0.05</td>
<td>2.73 ± 0.48</td>
<td>0.0168</td>
<td></td>
<td></td>
</tr>
<tr>
<td>100 m women</td>
<td>0.05</td>
<td>0.04</td>
<td>3.36 ± 0.46</td>
<td>2.74–0.1</td>
<td>0.0023</td>
</tr>
<tr>
<td>100 m men</td>
<td>0.05</td>
<td>2.98 ± 0.48</td>
<td>0.0023</td>
<td></td>
<td></td>
</tr>
<tr>
<td>200 m women</td>
<td>0.04</td>
<td>2.88–0.46</td>
<td>0.0138</td>
<td></td>
<td></td>
</tr>
<tr>
<td>200 m men</td>
<td>0.06</td>
<td>3.85–0.48</td>
<td>0.0145</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The missing data were not included because they were not significant.

Figure 2: Swimming speed of the annual top eight women (Panels A, C, E) and men (Panels B, D, F) competing at international level between 2001 and 2012 in breaststroke swimming in 50 m (Panels A, B), 100 m (Panels C, D) and 200 m (Panels E, F) in short course and long course.
Differences in swimming speed on short course and long course for female and male breaststroke swimmers: a comparison of swimmers at national and international level. OA Sports Medicine 2013 Sep 01;1(2):18.

Figure 3: Swimming speed and sex difference of the overall top ten female and male breaststroke swimmers in 50 m (Panel A), 100 m (Panel B) and 200 m (Panel C) competing at national level between 2000 and 2011. The p value is given in case of a significant difference between short course and long course swimming. 'NS' means no significance and indicates absence of significant difference.
Sex difference in breaststroke swimming speed

For all distances, the sex difference in breaststroke swimming speed was greater on the short than on the long course (Table 1 and 2). The sex difference in swimming speed at national level was on average 11.3 ± 1.6% [range: 9.7–12.9%] (Table 1 and Figure 3). Among the finalists from the World Championship the sex difference was higher on the short course than on the long course, too. The sex difference in swimming speed was on average 12.3 ± 1.1% [range: 11.2–13.3%] in all three distances.

Figure 3 shows that the longer the swim distance the lower the sex difference in swimming speed. Women at national level were 14% slower than men on the short course and 13% slower on the long course, with a significant difference in the 200 m long course (p = 0.03). In finalists from the World Championship, the sex differences were higher, but not significant, on the 50 m short than on the 50 m long course (Figure 4). Women were 11.8% slower than men on the short and 11.1% slower on the long course, with no difference for the 50 m short course (i.e., with significant difference in 100 m 10.7 versus 10.3%, p = 0.01; 200 m 11 versus 9.7%, no significance).

Discussion

The aims of this study were to examine (i) the difference in breaststroke swimming speed between short and long course and (ii) the change in swimming speed across the years in elite swimmers at both national and international level. The main findings of this study were (i) breaststroke swimming speed was 1.8–4.2% faster on the short than on the long course, (ii) swimming speed improved for both the short and long course during the last decade independently of sex and race distance, (iii) the sex difference in swimming speed was greater on the short course.

Figure 4: Swimming speed and sex difference of the overall top ten men and women breaststroke swimmers in 50 m (Panel A), 100 m (Panel B) and 200 m (Panel C) competing at international level between 2001 and 2012. The p value is given in case of a significant difference between short course and long course swimming. 'NS' means no significance and indicates absence of significant difference.
than long course for all distances and (iv) the longer the distance the more the sex difference in swimming speed decreased.

**Breaststroke swimming speed was faster on short than on long course**

Swimming speed was faster on the short than on the long course for 50 m, 100 m and 200 m. Due to the higher number of turns and push offs, swimming speed is faster on the short than on the long course. Breaststroke turns can account to one third of race time in 25 m pools. The anaerobic metabolism predominates on short events. This means an improvement in short events can be achieved by enhancement of anaerobic training. The connection between local fatigue due to increasing lactate values and increasing energy costs may explain the decrease in swimming skills. Stroke length decreases dramatically at a given lactate value and stroke rate increases in anaerobic sections. Therefore, the longer the race the lower the velocity which can be shown in our results.

**Improvement in breaststroke swimming speed across the years**

The second important finding was that swimming speed increased in both women and men on both courses over the years for swimmers at both national and international level. However, the improvements in swimming speed in athletes at international level were lower compared to swimmers at national level. Competitors at international level are closer on the maximum physiologically possible human frontiers so they cannot improve as much as national swimmers.

In addition to changes in anthropometric characteristics, improvements in training and psychological aspects, a new generation of swimsuits affected swimming speed. Wearing this new full-body swimsuits reduced passive drag. This was associated with a decreased energy coast and an increased distance per stroke. Although FINA prohibited wearing full-body wetsuits, swimming speed did not fall. The reason could be the use of new angled starting blocks, where the kick start was significantly faster than on the older starting blocks.

**Sex difference in breaststroke swimming speed in short versus long course**

The third important finding was that the sex differences in swimming speed were greater in the short than in the long course. Women achieved ~90% of the swimming speed of men in the short course which is in line with international data. Sharp et al. described that world records were faster in 25 m pools than in 50 m pools due to more turns and push offs and reduced blood lactate values. Additionally, the turns lead to a redistribution of the muscular load and physiological recuperation can occur.

Swimmers seemed to have improved their technic of turns over the years as well as their anaerobic performance (i.e., sprint). The decrease in velocity on long course could be related to the fact that endurance performance suffered due to the improved anaerobic performance due to larger muscle mass. This means the longer the course the higher the muscle fatigue which might impair the swimming technic because of less streamlining resulting in increasing drag. Thereby, an increase in energy coast and velocity cannot be sustained.

The fourth important finding was the longer the competition distance the lower were the differences in swimming speed between men and women. Lower energy costs are reported for women due to anthropometric values for long distances in swimming. Women have a lower hydrodynamic resistance and are more streamlined than men. Zuniga et al. suggested that women could improve their performances by reducing body fat, because a greater percentage of body fat may adversely affect swimming speed. Additionally, they have to build up fat-free weight to generating power.

The aerobic capacity is the main base for endurance performance. High endurance allows maintaining a high average velocity. Lower lactate levels were reported for women after competitions, which means a slower fatigue. Women competing at national level may have to have a higher percentage of slow twitch fibres and thereby improve endurance performance on the long course. Or they take more advantage of turns with longer wall push-off times resulting in faster final push-off velocities. The maximum power depends on metabolic energy, which depends on the anthropometric and technical character of the athlete. In well-trained swimmers, the size scaled cost of swimming is not depending upon age and sex. Additionally, psychological aspects may play a role and the greater expectation to win.

**Conclusion**

Elite breaststroke swimmers at both national and international level were ~3% faster in 25 m pools compared to 50 m pools for distances between 50 and 200 m, breaststroke swimming speed increased on short and long course over the years between 1.2 and 5.2% in elite swimmers competing at both national and international level independently of the sex and the distance. The sex difference in breaststroke swimming speed from 50 m to 200 m was close to 11% but appeared slightly greater in 50 m pools compared to 25 m pools. Future studies should investigate sex differences in short and long course for other swim strokes.

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All authors contributed to the concept on, design, and preparation of the manuscript, as well as read and approved the final manuscript.

All authors abide by the Association for Medical Ethics (AME) ethical rules of disclosure.


