Kinematic differences between front crawl sprint and distance swimmers at sprint pace

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Abstract

The purpose of this study was to use three-dimensional methods to determine whether there are distinct kinematic differences between sprint and distance front crawl swimmers when swimming at a sprint pace. Seven sprint and eight distance specialists performed four 25-m sprints through a 6.75-m$^3$ calibrated space recorded by six gen-locked cameras. The variables of interest were: average swim velocity, stroke length, stroke frequency, upper limb and foot displacement, elbow angle, shoulder and hip roll angles, duration of stroke phases, and the time corresponding to particular events within the stroke cycle relative to hand entry. Differences between sprint and distance swimmers were assessed with an independent t-test for each variable, in addition to effect size calculations. Differences between sprint and distance front crawl swimmers were generally small and not significant when swimming at a sprint pace. Differences were limited to temporal aspects of the stroke cycle. These findings suggest that coaches should not train sprint and distance specialists differently in terms of technique development.

Keywords: Swimming technique, sprint swimming, distance swimming

Introduction

Race distances in competitive freestyle swimming tend to be categorized as “sprint” or “distance” events. Races over 50 m and 100 m are classified as sprint events, while races of 400 m and more are classified as distance events. At the elite level, swimmers tend to specialize in a particular event, which suits their innate and conditioned physiological characteristics (McArdle, Katch, & Katch, 1996) in addition to their stroke mechanics and racing ability (Hohmann, Dierks, Luenhenschloss, Seidel, & Wichmann, 1999).

Researchers have reported that swimmers adjust the magnitude of the race parameters – average swim velocity, stroke frequency, and stroke length – in relation to the race distance (Cappaert, 1999; Keskinen & Komi, 1993; Pelayo, Sidney, Kherif, Chollet, & Tourny, 1996). It is well documented that sprint swimming is associated with a higher average swim velocity and stroke frequency, and a lower stroke length relative to distance swimming (Keskinen & Komi, 1993; Pelayo et al., 1996; Seifert, Chollet, & Brady, 2004). However, it is unclear whether swimmers specializing in sprint and distance events have similar magnitudes of these variables when swimming at a sprint pace.

The reviewed literature indicates that sprint and distance front crawl swimmers use distinct stroke characteristics to optimize performance (Cappaert, 1999; Costill, Maglischo, & Richardson, 1992; Ito & Okuno, 2002). Cappaert (1999) analysed sprint and distance Olympic and World Championship male swimmers during competition and reported that sprint swimmers used a deeper pulling pattern than the distance group (1.6 m vs. 1.0 m). However, the magnitudes of these values are large compared with other studies that have calculated maximum stroke depth for a group of sprinters (0.78 m: Deschodt, Rouard, & Monteil, 1996; 0.79 ± 0.04 m: Payton, Bartlett, Baltzopoulos, & Coombs, 1999), indicating methodological concerns. It has also been suggested that front crawl distance swimmers include more lateral motions of the upper limb than sprinters (Colwin, 2002; Maglischo, 2003). However, no study has quantified the upper limb lateral displacement characteristics of front crawl sprint and distance swimmers with three-dimensional (3D) methods to substantiate these possibilities. It is therefore necessary to investigate the vertical and
lateral displacement of the upper limb further to determine whether sprint and distance swimmers use different stroke paths when sprinting.

When changing from a distance to sprint pace, sprinters increase the relative duration of the propulsive phases (pull and push) and reduce the time spent in the non-propulsive phases (entry and recovery) with respect to the stroke cycle duration (Chollet, Chalies, & Chatard, 2000; Keskinen & Komi, 1993; Seifert et al., 2004). In contrast, distance swimming has been characterized by a prolonged entry phase and a reduced duration of the propulsive phases relative to sprint swimming (Chollet et al., 2000; Keskinen & Komi, 1993; Seifert et al., 2004). However, in previous studies only sprint swimmers were assessed in relation to the stroke phase durations over various swim speeds. It is therefore unclear whether distance swimmers would display characteristics similar to sprint swimmers when sprinting, or whether the stroke phase durations would mimic those associated with distance swimming.

The elbow angle is discussed regularly in the literature primarily due to its influence on the arm trajectory, efficiency and applied propulsive force by the arm during the underwater stroke cycle (Cappaert, 1999; Colwin, 1977; Counsilman, 1973; Deschodt et al., 1996; Haffner & Cappaert, 1999). Several authors have suggested that swimmers tend to exhibit a 90° elbow angle throughout the underwater stroke cycle (Colwin, 1977; Costill et al., 1992; Maglischo, 2003; Maglischo, Maglischo, & Santos, 1989). However, Wilke (1992) and Cappaert (1999) observed that sprinters tend to have a larger elbow angle (120° and 106.5° respectively) than distance swimmers, which is also greater than the “recommended” 90°. Unfortunately, no quantitative data in relation to sprint versus distance swimmers have been presented in the literature to substantiate these claims. Similarly, there is a lack of quantitative data to assess the elbow angle magnitude at particular events during the stroke cycle (e.g. beginning of pull phase, end of push phase) and contradictory opinions on how the elbow angle changes throughout the duration of the stroke cycle. Specifically, some authors have suggested that a 90° elbow angle should be maintained throughout the pull phase of the underwater stroke cycle (Costill et al., 1992; Maglischo, 2003), while others have expressed that the angle changes continuously (Counsilman, 1973; Vorontsov & Rumyantsev, 2000). Payton et al. (1999) supported the latter claim by reporting that male competitive sprint swimmers use a 45 ± 14° elbow angle range during the pull phase of the stroke cycle. Therefore, due to the lack of quantitative elbow angle data throughout the stroke cycle, it is important to examine this variable further and to assess whether it is influenced by the swimmer’s specialization.

As the arms rotate in front crawl swimming, the swimmer’s shoulders and hips roll independently about the body’s longitudinal axis. The importance and function of integrating this element into the front crawl stroke has been well documented by Psycharakis and Sanders (2010). In relation to sprint versus distance swimmers, Cappaert (1999) revealed that sprinters roll the shoulders less than distance swimmers, by an average of approximately 16°, due to the rapid nature of sprinting events. However, it is unclear whether sprint and distance swimmers roll the shoulders or hips with different magnitudes when sprinting or whether this is a consequence of the swim velocity as suggested by Castro and colleagues (Castro, Minghelli, Floss, & Guimaraes, 2003). Moreover, although the temporal aspects of the shoulders and hips rolling throughout a stroke cycle have been documented (Cappaert, Pease, & Troup, 1995; Psycharakis & Sanders, 2008; Sanders & Psycharakis, 2009), these variables have not yet been investigated in relation to sprint and distance swimmers.

Cappaert (1999) reported that sprint swimmers are characterized by a greater knee bend during the front crawl kicking action compared with distance swimmers (100.8° vs. 139.7°). It was suggested that an increased knee bend resulted in a greater knee range of motion, which was speculated as advantageous to propulsion (Cappaert, 1999). It was assumed that, as a consequence of the increased knee range of motion, the foot range of motion in terms of displacement would also be greater for sprint than for distance swimmers, but this remains to be established.

A limitation of previous studies that reported differences between sprint and distance swimmers (Cappaert, 1999; Costill et al., 1992; Ito & Okuno, 2002; Wilke, 1992) is that the swim pace was not considered as a factor. Thus, it is unclear whether front crawl sprint and distance swimmers differ due to their distance specialization or the actual race pace required for that distance. Such knowledge is important for coaches in terms of the technical instructions given to sprint and distance specialists when training. Therefore, the aim of this study was to determine, using 3D methods, whether there are distinct differences in the kinematics of sprint and distance front crawl swimmers when both groups swim at a sprint pace.

Methods

Participants

Fifteen male national and international standard front crawl swimmers (age 17.9 ± 2.3 years; mass 73.9 ± 8.7 kg; height 1.83 ± 0.07 m), comprising
seven sprint and eight distance specialists, volunteered to participate in the study. The criteria for participation were as follows: (a) specialized in their chosen distance event for a minimum of 2 years; (b) sprinter’s personal best for 50 m (long course) less than 24.60 s; (c) distance swimmer’s personal best for 400 m (long course) less than 4 min 10 s. The specified times were based on the 15 best performances at the Scottish National Championships (2007) for both the 50-m and 400-m freestyle events. The test procedures were approved by the university ethics committee and all swimmers provided written informed consent.

Participants were marked for two purposes: (a) to track the swimmer through the water and (b) to enable subsequent calculation of the inertial properties of the limbs using the elliptical zone method (Jensen, 1978). In the present study, black waterproof oil and wax-based cream, applied by a 40-mm diameter sponge, was used to mark the following 19 anatomical landmarks: the vertex of the head (using a swim cap), the right and left of the: tip of the third distal phalanx of the finger, wrist axis, elbow axis, shoulder axis, hip axis, knee axis, ankle axis, fifth metatarsophalangeal joint, and the tip of first phalanx (big toe).

Test procedure

The test session required each participant to swim four 25-m sprints. Each 25-m sprint was followed by a 25-m active swim recovery to the starting position and then a 2-min passive recovery period while remaining in the water. All swimmers were required not to breathe when swimming through the calibrated volume to avoid any possible effects on stroke kinematics. Therefore, swimmers were advised to familiarize themselves with this non-breathing protocol during their individualized warm-up. All swim trials were initiated from a push start to eliminate any possible influence that a dive may have on the stroke kinematics. Therefore, swimmers were advised to familiarize themselves with this non-breathing protocol during their individualized warm-up. All swim trials were initiated from a push start to eliminate any possible influence that a dive may have on the stroke kinematics ( Psycharakis & Sanders, 2008; Seifert et al., 2004).

The test session was conducted in a 25-m indoor swimming pool (average pool temperature 29.5 ± 0.2°C). The swimming volume was calibrated using a rectangular prism frame of the following dimensions: 4.5 m length (x), 1.0 m width (y), and 1.5 m height (z) enclosing a calibrated volume of 6.75 m³. The accuracy and reliability of the 3D coordinate calculation, using this particular frame, was established by Psycharakis and colleagues (Psycharakis, Sanders, & Mill, 2005). They concluded that the small errors were similar to, or better than, other frames of similar volume used in 3D studies, resulting in accurate and reliable 3D coordinate calculations. The calibration frame was recorded by six gen-locked JVC KY32 CCD cameras (four below and two above the water surface) and digitized to yield separate calibration files for the above- and below-water views using an Ariel Performance Analysis System, incorporating the direct linear transformation algorithms. All six cameras recorded the motion of the swimmer at a sampling frequency set at 50 fields per second and an electronic shutter speed of 1/120 s.

Data processing

One stroke cycle (defined as the period between the instant of entry of one hand to the instant of entry of the same hand) during each of the four 25-m sprints was selected for analysis. Ariel Performance Analysis System software was used to manually digitize the 19 body landmarks separately for above- and below-water views. Marker visibility was maximized by the use of four underwater cameras, which minimized the incidence of “guessed points”. Three-dimensional coordinates of the body landmarks were obtained for the above- and below-water cameras. The coordinates of the above- and below-water views were then combined into one single file representing continuous coordinates throughout the stroke cycle. This file was input to a bespoke MATLAB ( Mathworks, Inc.) analysis program to calculate all variables. During this process, a Fourier transform retaining six harmonics was used to smooth the raw data corresponding to the stroke cycle. The use of the Fourier series transform is regarded as highly appropriate when analysing periodic data, such as in swimming ( Bartlett, 1997), and avoids the problem of distortion at the ends of the data set encountered when using other types of filters.

Body segment parameter data were obtained using the “eZone” program ( Deffeyes & Sanders, 2005) based on the elliptical zone method established by Jensen (1978). These data were input to the MATLAB ( Mathworks, Inc.) analysis program for calculation of whole-body centre of mass position and derived centre of mass velocity.

Data analysis

The average horizontal swimming velocity was calculated by dividing the swimmer’s mean centre of mass horizontal displacement by the time to complete one stroke cycle. Stroke frequency was the inverse of the time (seconds) to complete one stroke cycle, which was then multiplied by 60 to yield units of strokes per minute. Stroke length was the horizontal displacement of the centre of mass during one stroke cycle.

The vertical motion of the upper limb was represented by the z displacement (m) of the third
distal phalanx of the finger, wrist axis, and elbow axis. The z displacement (m) of the first phalanx tip (big toe) was representative of the foot’s vertical motion. Both the vertical motion of the upper limb and foot segments were referenced to an external point. The lateral motion of the upper limb, with respect to the swimmer’s centre of mass, was calculated as the absolute y displacement (m).

Shoulder and hip roll angles were each determined as the angle between the unit vector of the line joining the shoulders and hips respectively, projected onto the yz plane (i.e. the plane perpendicular to the swimming direction) and the horizontal. Computationally, this is: arc-tangent ($S_z/S_y$) and arc-tangent ($H_z/H_y$), where $S_z$ and $S_y$ are the z and y components of the shoulder unit vector and $H_z$ and $H_y$ are the z and y components of the hip unit vector.

The elbow angle was quantified as the arc-cosine of the dot product of the upper arm and lower arm unit vectors. The elbow angle was quantified corresponding to four instants within the underwater stroke cycle, namely: $X2 =$ beginning of finger moving horizontally backward (“first back”), $X3 =$ finger vertically aligned with the shoulder (“shoulder x”), $X4 =$ end of backwards movement (“end back”), $X5 =$ finger re-entry (“recovery”). These instants were calculated based on the horizontal displacement of the finger and shoulder during the stroke cycle (Figure 1). The elbow angle range during the pull and push phases was calculated as: $X3 - X2$ and $X4 - X3$ respectively (refer to Figure 1).

Four separate phases were identified; entry, pull, push, and recovery (Chollet et al., 2000; Seifert et al., 2004). Each phase, within every stroke cycle, was determined from the swimmer’s horizontal (x) and vertical displacement (z) of the finger and noting the time corresponding to these displacements. Figure 1 illustrates the definition of each discrete phase. Time was expressed as a percentage of the stroke cycle (%SC).

All kinematic data were averaged across the four trials for each swimmer, and these means were used to calculate group means for the sprint and distance swimmers.

To assess the digitizing reliability, one complete stroke cycle was randomly selected from a swimmer and digitized 10 times for all six camera views. The standard deviation (s) and coefficient of variation (CV) for each variable of interest were calculated across all digitizations as an indication of reliability.

Figure 1. Analysis of the horizontal displacement of the finger and shoulder was used to define instances throughout the stroke cycle. Elbow angle data and stroke phase durations were then calculated corresponding to when these instances occurred. Instances were defined as follows: $X1 =$ finger entry, $X2 =$ beginning of finger moving horizontally backward (“first back”), $X3 =$ finger vertically aligned with the shoulder (“shoulder x”), $X4 =$ end of backwards movement (“end back”), $X5 =$ finger re-entry (“recovery”).
Statistical analysis

An independent t-test was used to assess statistical differences between sprint and distance swimmers, with a confidence level of $P < 0.05$ accepted as significant. The processed data were analysed using the Statistical Package for Social Sciences (SPSS) version 14.0.

The effect size ($d$) for each variable was calculated in accordance with Cohen (1988) to measure the magnitude of difference between the sprint and distance swimmers relative to the variability. This was to provide an indication of the magnitude of effects, particularly where differences may have approached but not reached statistical significance. The criteria for interpreting the absolute effect size were based on Cohen’s (1988) suggestion that effect sizes of 0.2 are small, 0.5 moderate, and 0.8 large.

Results

Reliability

The reliability calculations showed that the effect of digitizing errors for each of the variables tested was small (Table I). Means, standard deviations, $P$-values of the t-tests, and effects sizes are displayed in Table II for the majority of variables tested.

Race parameters

Sprint and distance swimmers were not significantly different in relation to the average horizontal swimming velocity, stroke length or stroke frequency as denoted by the significance level and small effect sizes.

Upper limb displacement and elbow angle

None of the upper limb displacement variables or the magnitudes of elbow angle at the specified instants throughout the stroke cycle were significantly different between the sprint and distance swimmers.

Stroke phase durations

The durations (%SC) of the entry ($d = 0.73$), push ($d = -0.31$), and recovery ($d = -0.15$) phases were not significantly different between groups. The pull phase duration was significantly different between the groups ($P = 0.02$) with a large effect size ($d = -1.40$). Figure 2 indicates that the distance swimmers spent longer in the pull phase than the sprinters.

Shoulder and hip roll

The magnitude of the total shoulder roll angle was not significantly different between groups and the effect size was small. The magnitude of total hip roll angle was not significantly different between sprint and distance swimmers and the effect size was moderate. The occurrence of both maximum left and right shoulder roll angle was significantly different between groups with a large effect size. The sprint specialists obtained maximum shoulder roll angle later in the stroke cycle than the distance specialists. Occurrence of maximum left or right hip roll angle was not significantly different between groups with a moderate effect size.

Foot vertical displacement

The vertical ranges of motion of the left and right feet were not significantly different between the groups with moderate effect sizes.

Discussion

The finding that sprint and distance specialists do not differ with respect to average swimming velocity, stroke length or stroke frequency suggests that the two groups use similar race parameter characteristics to optimize sprint performance. It is proposed that both swim groups adjust these parameters...
Table II. Data and statistical comparisons of the differences between sprint and distance specialists for the following variables: race parameters, upper limb and foot displacement, elbow angle, shoulder and hip roll variables (mean ± s).

<table>
<thead>
<tr>
<th>Variables</th>
<th>Sprint group</th>
<th>Distance group</th>
<th>P-value</th>
<th>Effect size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Swim velocity (m \cdot s^{-1})</td>
<td>1.81 ± 0.07</td>
<td>1.80 ± 0.05</td>
<td>0.77</td>
<td>0.17</td>
</tr>
<tr>
<td>Stroke length (m)</td>
<td>2.0 ± 0.2</td>
<td>2.0 ± 0.1</td>
<td>0.64</td>
<td>0.24</td>
</tr>
<tr>
<td>Stroke frequency (cycles \cdot min^{-1})</td>
<td>54.7 ± 5.1</td>
<td>55.4 ± 3.7</td>
<td>0.76</td>
<td>−0.17</td>
</tr>
<tr>
<td>Max. finger depth (m)</td>
<td>0.66 ± 0.05</td>
<td>0.66 ± 0.06</td>
<td>0.93</td>
<td>0.06</td>
</tr>
<tr>
<td>Max. wrist depth (m)</td>
<td>0.51 ± 0.06</td>
<td>0.51 ± 0.05</td>
<td>0.97</td>
<td>0.04</td>
</tr>
<tr>
<td>Max. elbow depth (m)</td>
<td>0.31 ± 0.06</td>
<td>0.30 ± 0.05</td>
<td>0.68</td>
<td>0.23</td>
</tr>
<tr>
<td>Max. finger width (m)</td>
<td>0.39 ± 0.07</td>
<td>0.39 ± 0.07</td>
<td>0.90</td>
<td>−0.05</td>
</tr>
<tr>
<td>Max. wrist width (m)</td>
<td>0.36 ± 0.05</td>
<td>0.38 ± 0.04</td>
<td>0.35</td>
<td>−0.45</td>
</tr>
<tr>
<td>Max. elbow width (m)</td>
<td>0.33 ± 0.06</td>
<td>0.31 ± 0.04</td>
<td>0.49</td>
<td>0.40</td>
</tr>
<tr>
<td>Finger width range (m)</td>
<td>0.32 ± 0.05</td>
<td>0.36 ± 0.11</td>
<td>0.33</td>
<td>−0.53</td>
</tr>
<tr>
<td>Wrist width range (m)</td>
<td>0.27 ± 0.04</td>
<td>0.30 ± 0.06</td>
<td>0.19</td>
<td>−0.71</td>
</tr>
<tr>
<td>Elbow width range (m)</td>
<td>0.21 ± 0.04</td>
<td>0.20 ± 0.04</td>
<td>0.86</td>
<td>−0.09</td>
</tr>
<tr>
<td>Elbow angle: first back (°)</td>
<td>151.1 ± 8.7</td>
<td>151.0 ± 9.8</td>
<td>0.98</td>
<td>0.02</td>
</tr>
<tr>
<td>Elbow angle: shoulder x (°)</td>
<td>103.2 ± 9.3</td>
<td>104.2 ± 6.3</td>
<td>0.81</td>
<td>−0.13</td>
</tr>
<tr>
<td>Elbow angle: end back (°)</td>
<td>147.8 ± 7.9</td>
<td>147.9 ± 8.5</td>
<td>0.99</td>
<td>−0.01</td>
</tr>
<tr>
<td>Elbow angle: re-entry (°)</td>
<td>153.0 ± 10.0</td>
<td>154.7 ± 11.2</td>
<td>0.76</td>
<td>−0.16</td>
</tr>
<tr>
<td>Elbow angle: range of pull (°)</td>
<td>48.0 ± 9.4</td>
<td>46.8 ± 7.4</td>
<td>0.80</td>
<td>0.14</td>
</tr>
<tr>
<td>Elbow angle: range of push (°)</td>
<td>44.7 ± 13.2</td>
<td>43.7 ± 11.9</td>
<td>0.89</td>
<td>0.08</td>
</tr>
<tr>
<td>Total shoulder roll (°)</td>
<td>106.6 ± 7.3</td>
<td>106.1 ± 4.9</td>
<td>0.89</td>
<td>0.06</td>
</tr>
<tr>
<td>Total hip roll (°)</td>
<td>36.7 ± 9.5</td>
<td>40.0 ± 7.2</td>
<td>0.46</td>
<td>−0.40</td>
</tr>
<tr>
<td>Time to max. left shoulder roll (%SC)</td>
<td>34.1 ± 3.1</td>
<td>26.7 ± 5.1</td>
<td>0.01*</td>
<td>1.72#</td>
</tr>
<tr>
<td>Time to max. right shoulder roll (%SC)</td>
<td>82.5 ± 5.2</td>
<td>75.3 ± 6.0</td>
<td>0.03*</td>
<td>1.29#</td>
</tr>
<tr>
<td>Time to max. left hip roll (%SC)</td>
<td>22.5 ± 5.9</td>
<td>24.3 ± 6.0</td>
<td>0.57</td>
<td>−0.30</td>
</tr>
<tr>
<td>Time to max. right hip roll (%SC)</td>
<td>75.8 ± 7.7</td>
<td>72.7 ± 9.7</td>
<td>0.51</td>
<td>0.35</td>
</tr>
<tr>
<td>Max. left foot depth (m)</td>
<td>0.41 ± 0.06</td>
<td>0.39 ± 0.05</td>
<td>0.48</td>
<td>0.38</td>
</tr>
<tr>
<td>Max. right foot depth (m)</td>
<td>0.41 ± 0.07</td>
<td>0.39 ± 0.05</td>
<td>0.37</td>
<td>0.48</td>
</tr>
</tbody>
</table>

*Significant at P < 0.05. #Large effect size, > 0.80. For the definitions when elbow angles were calculated throughout the stroke cycle, refer to Figure 1.

Figure 2. Stroke phase durations for the sprint and distance specialists when sprinting. Mean stroke phase duration data are indicated. Bars represent 95% confidence interval of the true mean. *Significant at P < 0.05.

According to the physiological demands and hydrodynamic characteristics of swimming at a given velocity and not in relation to the specialization of the swimmer.

The finding that the sprint and distance swimmers in the present study used similar hand depth magnitudes when swimming at a sprint pace is at odds with the study of Cappaert (1999), in which both groups were reported to use different hand depth magnitudes when swimming at their respective paces. The findings that both groups stroke with a similar vertical and lateral displacement of the upper limb may have implications for coaching. Coaches should not train or emphasize different pathways of the upper limb for either sprint or distance specialists.

Wilke (1992) and Cappaert (1999) both found that sprint and distance specialists used different magnitudes of elbow angle during the underwater stroke cycle when swimming at their respective race paces. In the present study, both groups used similar elbow angle magnitudes throughout the stroke cycle when sprinting. Based on these results, it is recommended that coaches do not encourage sprint and distance swimmers to pull with different elbow angle magnitudes during the underwater stroke cycle when sprinting, as both groups use similar magnitudes to optimize sprint performance.

Conflicting views have been expressed in the literature, with some researchers advocating that the elbow angle does not change throughout the underwater stroke cycle (Costill et al., 1992), while others have stated that it changes continuously (Payton et al., 1999). This study supports the claim that the elbow angle changes continuously during the underwater stroke cycle when sprinting. Based on
the results of the present study, a typical swimmer enters the upper limb into the water with 14° elbow flexion, which progressively flexes to 21° at the catch position and 72° at the pull to push phase transition. Thereafter, elbow flexion decreases to 44° at the end of the push phase and extends to 52° as the hand exits the water. It is therefore recommended that poolside demonstrations elicit an underwater stroke cycle that incorporates a continuously changing elbow angle, and drills that promote this skill are included within sprint training programmes to aid further development.

One of the main differences between the sprint and distance specialists was the time spent within the pull phase. Researchers have previously linked differences in stroke phase durations to the variation of hand velocity and/or acceleration within that particular phase (Chollet et al., 2000; Lerda & Cardelli, 2003). Therefore, hand velocity and acceleration for the present study were examined subsequent to the analysis of the a priori variables of interest. These variables were calculated based on the combined displacement of the third distal phalanx and wrist, then averaged, over the time taken between each field. Both the horizontal and vertical components of hand velocity and acceleration were calculated. It was found that the sprinters had a significantly ($P = 0.05$) faster average velocity and acceleration of the hand than the distance swimmers within the pull phase, both in terms of the horizontal and vertical components. In agreement with previous research (Chollet et al., 2000; Lerda & Cardelli, 2003), it is suggested that the shorter duration of the pull phase by the sprint specialists may be attributed to the faster hand velocity/acceleration within that particular phase. However, because there was no difference between sprint and distance swimmers in terms of sprint performance, a shorter pull phase concomitant with a faster hand velocity/acceleration within this phase does not appear to be advantageous across a 25-m sprint. On the other hand, it is possible that due to the rapid motions of the limbs to ensure high propulsive forces repetitively when sprint training, the sprint specialists may have developed a stronger and more powerful musculature than the distance specialists resulting ultimately in the ability to execute a shorter pull duration. Based on these findings, for sprint specialists, coaches should incorporate specific strength exercises that help develop those muscles utilized in the pull phase, such as the latissimus dorsi, rotator cuff, triceps, and biceps. Girold and colleagues (Girold, Maurin, Dugue, Chatard, & Millet, 2007) reported that combining swimming sessions with dry-land strength exercises or with in-water resisted and assisted sprint exercises led to greater strength gains in the elbow flexor and extensor muscle groups compared with swim training alone.

The finding that sprint and distance specialists have a similar magnitude of total shoulder and hip roll angle when sprinting is at odds with the findings of Cappaert (1999) for distance and sprint swimmers swimming at their race paces. This indicates that previous differences in hip and shoulder roll between sprint and distance swimmers when swimming at their respective race paces are due to the pace itself rather than the specialization of the swimmer. The magnitudes of total shoulder roll in the present study were similar to those reported by Psycharakis and Sanders (2008), although the total hip roll values were found to be 10–14° lower. In a subsequent study, Sanders and Psycharakis (2009) reported that the kicking actions had a minor influence on shoulder roll but a considerable influence on hip roll and hypothesized that the kicking action damped the hip rotation movement. Therefore, it is suggested that the differences in total hip roll magnitude between the present study and that of Psycharakis and Sanders (2008) are due to the kicking action contribution. That is, in the present study all swimmers performed four 25-m swims of maximal effort with sufficient rest, whereas all swimmers in Psycharakis and Sanders (2008) were required to swim a continuous 200-m maximum swim. The different race distance and swimming velocity may have influenced the kicking action and thus the total hip roll magnitude.

Although the sprint and distance swimmers rolled through similar ranges when sprinting, there were interesting differences in the timing of shoulder roll expressed as a percentage of stroke cycle. The sprinters obtained maximum shoulder roll, to both sides, later within the stroke cycle than the distance swimmers. Based on the fact that all stroke cycles had an equal duration (as they were expressed as a percentage) and no difference was found between groups in relation to the stroke frequency, it is suggested that the velocity or acceleration of the shoulders rotating may have differed between groups. However, further study involving the quantification of net torques is required to explain these differences. Moreover, Psycharakis and Sanders (2008) found that handedness may affect the temporal characteristics of the shoulders rotating; however, handedness was not calculated in this study. It was also found that both groups obtained maximum shoulder roll as one upper limb travelled through the transition from entry to pull phase, while the other limb recovered over the water surface. As a result, both swim groups and coaches should be kinaesthetically aware of the upper limbs in relation to each other when maximally rolling the shoulders to both sides.
Given the finding that sprint and distance swimmers do not differ with respect to the kicking depth when sprinting, it would be interesting to determine whether this amplitude is consistent across paces, so that coaches can provide accurate feedback in relation to this variable to swimmers who train and compete across a range of swim practices.

Conclusion

Based on the findings of the present study, it appears that technique differences between sprint and distance swimmers are due predominantly to the race pace rather than the distance specialization of the swimmer. The shorter duration of the pull phase by sprint specialists may be linked to a trained ability to move the hand through this phase at speed compared with distance specialists. Relative to the distance swimmers, the later attainment of maximum shoulder roll by the sprint group requires further investigation. In terms of technique development, there is no evidence from this study that the technique of sprint and distance specialists needs to be developed differently through alternate training practices.

References


