DOES STROKE RATE DETERMINE SWIMMING VELOCITY VALUES AND COORDINATIONS?

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ABSTRACT

The purpose of this study was to assess the effects of stroke rate (SR) on the reproducibility of swimming velocity (V) and index of coordination (IdC) values in a front crawl swimming sequence. The procedure was twofold. In the first procedure, 30 expert and non expert subjects performed two tests of 4 x 12.5-m. In the first test, they were requested to swim at a spontaneous low, average, fast and maximal speed. V and SR were measured. In the second test, SR was imposed at the values registered previously and V was compared with previous V values. Results showed equality between V values whatever the test step and the higher the SR values, the lower the difference in V values between the two test conditions. The results were similar in experts and non experts. In the second procedure, 9 expert swimmers performed two front crawl tests of 4 x 12.5-m. In each test, they were requested to swim the fastest with a SR set at 20, 30, 40, 50 cycles.min\(^{-1}\). IdC was calculated and compared for the same SR. Results showed equality between IdC only when SR was higher than 40 cycles.min\(^{-1}\). We concluded of the intensities control and skills stabilisation by the SR for the swimming coaches. We suggested that coordination could be explain by dynamic concepts.

Key words : Stroke rate, Velocity, Index of Coordination.

INTRODUCTION

One of the main goals of training is to improve and stabilise technique skills in order to swim faster. Arms coordination is one of the most important factor to produce propulsive forces (Chollet, 1997). Three major models are usually described in front crawl swimming. The catch-up model describes a lag time between the propulsive phases of the two arms. The opposition model describes a series of propulsive actions: one arm begins the pull phase when the other is finishing the push phase. The superposition model describes an overlap in the propulsive phases. Studies in front crawl showed that the mode of coordination adopted depends on the type of race and of the performance level. When swim velocity of race increases, arm coordination slides from catch-up to opposition (Maglischo,1993). Only expert population uses superposition (Chatard et al, 1990; Kolgomorov & Duplisheva, 1992). Hence, the adoption of a given coordination mode seems to depend on the constraints that govern the system. From a dynamical systems point of view, these results suggest that the evolution of a so-called control parameter (in the present case, swim velocity) produces a transition between attractive states (Kelso, 1995). Seifert et al (2001) showed that the index of coordination (Chollet,2000) is a good candidate as order parameter for capturing the main features of arms coordination and its from a pattern to another. Their results suggested the role of stroke rate, as control parameter, in the dynamics of these transitions.

Thus, the purpose of this study was to assess the effects of stroke rate (SR) as a constraint on the reproducibility of swimming velocity values and coordination patterns in a front crawl swimming sequence.

METHODS

The procedure was twofold.

Procedure 1
30 subjects (11 national level swimmers (G1) and 19 non expert swimmers (G2)) performed two front crawl tests of 4 x 12.5-m. In the first one, subjects were requested to swim at a spontaneous low, average, fast and maximal speed. Velocity (V) was measured from two steady S-VHS video-cameras running in sychnrone, set 12.5-m apart along the central part of the pool and connected to a timer.
Stroke rate (SR) was measured in the same area using a Seiko frequency-meter (base 3). In the second test, SR was set and imposed at the values registered previously in the first test by means of a bleeper fitted in the swim cap. V was recorded according to the previous protocol and was compared with previous V values recorded in the first test by applying the technique suggested by Bland and Altman. To compare two velocities, the difference in V was plotted against mean V values to explore the systematic difference. The mean difference (Bias) and the limit of agreement (Bias plus and minus two standard deviation (SD) were graphically indicated. The relationships were tested using Pearson’s correlation.

Procedure 2
Nine well trained national level swimmers (6 males, 3 females) performed two front crawl tests of 4 x 12.5-m. In each test, subjects were requested to swim as fast as possible with a stroke rate set at 20, 30, 40, 50 cycles.min\(^{-1}\). SR was imposed using the first procedure protocol. Subjects were asked to hold their breath in order to avoid modifications in coordination due to breathing. The rest period between each trial was at least 5 minutes. Moreover, at the end of the two tests, subjects were asked to swim at SR = 55 cycles.min\(^{-1}\) during one trial. The stroke phases and modes of arm coordination were analysed underwater with two video cameras (S. VHS Panasonic) set at rapid shutter speed (1/1000 of a second); 50 pictures per second were filmed. One camera filmed the swimmer from a frontal view, the other in profile. They were connected to a double-entry audio-visual mixer, a chronometer, a monitoring screen and a video recorder that recorded the mixed picture (camera 1 in the upper half of the screen and camera 2 in the lower half with the chronometer). A third independent camera filmed all trials of each swimmer in profile from above the pool. This camera allowed us to quantify the V and SR, from which stroke length (SL) was calculated. Arm coordination was quantified using the Index of Coordination (IdC). IdC was compared at the same SR using Bland and Altman’s test.

Statistical Analyses
The relationships between the IDC values of the two test were examined by simple linear regression analyses (Bravais-Pearson coefficient). A one-way ANOVA and the Bonferroni post hoc test were used to study the evolution of IdC, V and SL in relation with SR values. A 95% level of confidence was accepted for all comparisons.

RESULTS

Procedure 1
Mean values for V, SR and SL for each trial are presented in table 1 for the two groups (G1 and G2). V and SL observed in G1 were statistically significantly higher than those in G2. SR recorded in G2 was significantly higher than in G1.

Table 1: Velocity, Stroke Length and Stroke rate: Mean values measured during the two tests.

<table>
<thead>
<tr>
<th>Groups</th>
<th>Velocities (m.s(^{-1}))</th>
<th>Stroke length (m.cycle(^{-1}))</th>
<th>Stroke rate (cycles.min(^{-1}))</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>low</td>
<td>average</td>
<td>fast</td>
</tr>
<tr>
<td>G1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>G2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Velocity (m.s(^{-1}))</td>
<td>1.05</td>
<td>0.87</td>
<td>1.15</td>
</tr>
<tr>
<td>±0.1</td>
<td>±0.12</td>
<td>±0.12</td>
<td>±0.12</td>
</tr>
<tr>
<td>Stroke length (m.cycle(^{-1}))</td>
<td>2.23</td>
<td>1.74</td>
<td>2.18</td>
</tr>
<tr>
<td>±0.34</td>
<td>±0.24</td>
<td>±0.28</td>
<td>±0.25</td>
</tr>
<tr>
<td>Stroke rate (cycles.min(^{-1}))</td>
<td>28.3</td>
<td>29.95</td>
<td>31.68</td>
</tr>
<tr>
<td>±2.8</td>
<td>±3.8</td>
<td>±3.8</td>
<td>±3.8</td>
</tr>
</tbody>
</table>

Note: Statistically different from G1 (p<.05)

Bland and Altman graphic analysis showed equality between V values whatever the test step. The correlation coefficient values were significant with p<0.0001 and the higher the SR values, the lower the difference in V values between the two test conditions. Moreover, the linear regression was the closest to y=x equation in maximal speed test (y = 0.94x + 0.65). The results were similar between experts and non experts.
Fig 1: Time comparison between two sequences of front crawl swimming performed with the same SR. The middle line represents the mean of difference between all the trials (=-0.13s). The upon line represents bias + 2SD = 0.99 s. The line on the lower part represents bias – 2SD = -1.25 s.

Procedure 2:
Mean values of V, SL and IdC recorded during the two tests and during the trial at SR = 55 cycles.min⁻¹ are presented in table 2. V and IdC increased significantly in relation to SR whereas SL decreased (p<0.05). When SR was lower than 55 cycles.min⁻¹, all subjects swam with catch-up coordination. Two types of catch-up coordination when SR = 20 cycles.min⁻¹ can be noticed. An usual coordination type (5 subjects) with the pull beginning before the entry and catch of the other hand in the water. An unusual type (4 subjects) describing an overlap in the catch phases. When SR is higher than 50 cycles.min⁻¹, five subjects adopted superposition coordination.

Table 2: Mean (±SD) velocity, stroke length and IdC values measured during the two tests.

<table>
<thead>
<tr>
<th>Stroke rate (SR)</th>
<th>SR = 20 cycle.min⁻¹</th>
<th>SR = 30 cycle.min⁻¹</th>
<th>SR = 40 cycle.min⁻¹</th>
<th>SR = 50 cycle.min⁻¹</th>
<th>SR = 55 cycle.min⁻¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>Velocity (m.s⁻¹)</td>
<td>1.11±0.12</td>
<td>1.29±0.16</td>
<td>1.42±0.18</td>
<td>1.53±0.13</td>
<td>1.63±0.14</td>
</tr>
<tr>
<td>Stroke length (m.cycle⁻¹)</td>
<td>3.29±0.35</td>
<td>2.68±0.46</td>
<td>2.17±0.27</td>
<td>1.97±0.53</td>
<td>1.84±0.17</td>
</tr>
<tr>
<td>IdC</td>
<td>-20.07±3.24</td>
<td>-15.69±4.74</td>
<td>-9.13±3.69</td>
<td>-3.63±2.49</td>
<td>-0.44±2.01</td>
</tr>
</tbody>
</table>

Note: ¹ Statistically different from the previous SR (p<.05) ² Statistically different from the second previous SR (p<.05)

Bland and Altman graphic analysis showed equality between IdC whatever the SR step. However, the limits of agreement for SR=20 (SD = ±5.6) and SR=30 (SD = ±3.24) are too important in order to allow us to conclude of the reproducibility of the IdC. Thus, the results showed statistical equality only for SR = 40 and 50 cycles.min⁻¹. The correlation coefficient values were significant with p<0.05 only for SR = 30, 40 and 50 cycles.min⁻¹. The higher the SR values, the lower the difference in IdC values between the two test conditions. Moreover, the linear regression was the closest to y=x equation for SR = 50 cycle.min⁻¹ (y = 0.77x - 0.65).
DISCUSSION

SR seemed to determine strongly swimming V values and particularly when SR is higher than 40 cycles.min\(^{-1}\). These results could allow swimming coaches to control exercise intensities using SR but also to stabilise and memorise race velocity. Indeed, technical work in swimming is often completed without instruction about SR in relation to speed, especially around maximal intensities. The similar results obtained with the second procedure denoted that SR determined IdC values when SR was high. From a biomechanical point of view, these results showed the importance of coordination mode in propulsive efficiency when SR is high. The reproducibility of velocity could be explained by the stability of coordination. High SR values could be used to stabilise technical skills in order to swim fast. These conclusions could be taken in account to specify and control taper training programme.

The dynamical approach to motor coordination provides an interesting account for explaining changes and stability of coordination modes in cyclical tasks (Nourrit et al., 2000). Preferential coordination modes (attractors) seem to emerge from the interplay of constraints (control parameters). Procedure 2 gave evidence for two types of attractors when SR was 20 cycles.min\(^{-1}\): an usual catch-up and a catch up with overlap in the catch phases. Between 20 and 50 cycles.min\(^{-1}\), the only preferred coordination mode would be the usual catch-up and when SR was higher than 50 cycle min\(^{-1}\), two attractors appeared with catch-up and superposition. The present results clearly suggest that SR could be considered as the control parameter in this particular situation. Arm coordination seems to emerge from an interplay of constraints which is summed up by the SR. It could be hypothesised that the higher the SR values, the lower the number of options to swim (degrees of freedom (Bernstein, 1967)). Indeed, environmental properties change in relation to velocity of the arm and could block the swimmer in a pattern whether SR is high. This could be put forward to explain why the spontaneously adopted IdC is dependent on SR when values are higher than 40 cycles.min\(^{-1}\). These data suggest that expert coordination (superposition) is rather linked to the capacity to swim with high SR rather than to a general motor program. This statement will be tested in a next future.
REFERENCES