Factors affecting the underwater phase of the swimming start?

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My Story So Far..

• 5 years experience at the AIS.
• Honours degree – Swimming Competition Analysis
• PhD – Factors affecting the underwater phase of the swimming start.
• Biomechanist (Swimming and Athletics) – Victorian Institute of Sport.
The AIS Pool

- 10 lane 50 m pool with movable boom.
- Wetplate Analysis System
- 28 fixed cameras
- Drag testing with a dynamometer
• Start performance is highly related to overall competition performance.
• The use of the kick-start has been proven to be advantageous.
• The kick-start technique has not widely been researched.
• Even less research on the underwater phase of the kick-start technique.
Overall PhD Aim

To investigate the factors that affect the underwater phase of the swimming start.
Specific Aims

• To use a novel multi-disciplinary approach to investigate the swimming start.
• To use biomechanical feedback to train swimmers to their ideal underwater trajectory
PhD Outline

- Study 1 – Reliability of the Wetplate Analysis System.
- Study 2 – Characteristics of an elite swimming start.
- Study 3 – Key parameters of elite swimming start performance.
- Study 4 – Do swimmers always perform better using their preferred technique?
- Study 5 – Comparing three underwater trajectories
- Study 6 – How does drag affect the underwater phase of the swimming start?
- Study 7 – Can biomechanical feedback be used to change the underwater trajectory of the swimming start?
Study 1 - Reliability of the Wetplate Analysis System.

**Aim:** To establish the reliability of Wetplate Analysis System.

Multiple studies had previously used this system, but the reliability of this system had not yet been formally documented (Honda 2010, 2012; McCabe 2012; Nguyen 2013).

The Wetplate Analysis System

- Entry distance (m)
- Reaction time (s)
- Take-off horizontal velocity (m.s\(^{-1}\))
- Take-off vertical velocity (m.s\(^{-1}\))
- Time in the air (s)
- Average acceleration (m.s\(^{-1}\))
- CoG angle of entry (degrees)
- Dive angle (degrees)
- Entry velocity (m.s\(^{-1}\))
- Entry hole diameter (m)
- Head entry time (s)
- Entry hole distance (m)
- Peak footplate force (N)
- Peak grab force (N)
- Peak horizontal force (N)
- Peak vertical force (N)
- Peak power per kilogram (w/kg)
- Mass of swimmer (kg)
- 5 m, 7.5 m, 10 m, 15 m split times (s)
- Time after entry of first kick (s)
- Time of first kick (s)
- Horizontal Distance of Max depth (m)
- Max Depth of Head (m)
- Time at Max Depth (s)
- Time Underwater in Accent (s)
- Time Underwater in Decent (s)
- Total Time Underwater (s)
- Distance of first kick (m)
- Breakout distance (m)
- Breakout time (s)
- Underwater velocity (m.s\(^{-1}\))
- Max depth (m)
- Time of full submersion (s)

(Mason et al. 2012)
WETPLATE CAMERA LOCATIONS – relative to start end and water surface

- 2.0m
- 1.5m
- 1.7m
- 1.6m
- 5.6m
- 12.8m

Water Level
Methods

• 14 elite swimmers performed 2 maximal effort dives to 15 m on two separate testing sessions.
• 4 trials per athlete total.
• Intra-Class Correlations were determined for each parameter.
• Each parameter’s reliability was then classed as poor, fair, good or excellent.
Results

• All parameters were classed as excellent reliability except for Peak Vertical Force and Time of maximum Depth. — This may be due to the variable nature of these parameters.
Study 2 – Characteristics of an elite swimming start.

• **Aim:** How do elite swimmers currently utilise the OMEGA OSB11 starting block.

• 52 retrospective Wetplate trials were included in the analysis:
  — 29 Male, 23 Female (22 ± 0.5 y)
  — 39 Olympians (30 Olympic Medallists)
  — 14 World Championship representatives
  — 39 Freestyle and 13 Butterfly

## Start Performance Breakdown

<table>
<thead>
<tr>
<th>Sub-Phase</th>
<th>Male</th>
<th>Female</th>
</tr>
</thead>
<tbody>
<tr>
<td>On-Block</td>
<td>12% (0.72 s)</td>
<td>11% (0.77 s)</td>
</tr>
<tr>
<td>Flight</td>
<td>5% (0.29 s)</td>
<td>4% (0.29 s)</td>
</tr>
<tr>
<td>Underwater</td>
<td>61% (3.72 s)</td>
<td>52% (3.67 s)</td>
</tr>
<tr>
<td>Free Swimming</td>
<td>22% (1.39 s)</td>
<td>33% (2.34 s)</td>
</tr>
</tbody>
</table>
## Gender Differences

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Male</th>
<th>Female</th>
<th>Difference in Mean</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Take-off Horizontal Velocity (m·s⁻¹)</td>
<td>4.85 ± 0.17</td>
<td>4.33 ± 0.19</td>
<td>0.52</td>
<td>0.00*</td>
</tr>
<tr>
<td>Entry Velocity (m·s⁻¹)</td>
<td>6.94 ± 0.11</td>
<td>6.59 ± 0.14</td>
<td>0.35</td>
<td>0.00*</td>
</tr>
<tr>
<td>Head Entry Time (s)</td>
<td>1.01 ± 0.05</td>
<td>1.06 ± 0.05</td>
<td>0.05</td>
<td>0.01*</td>
</tr>
<tr>
<td>Peak Footplate Force (N)</td>
<td>1.70 ± 0.26</td>
<td>1.36 ± 0.18</td>
<td>0.34</td>
<td>0.00*</td>
</tr>
<tr>
<td>Peak Horizontal Force (N)</td>
<td>1.33 ± 0.15</td>
<td>1.11 ± 0.15</td>
<td>0.22</td>
<td>0.00*</td>
</tr>
<tr>
<td>Max Depth of Head (m)</td>
<td>-1.05 ± 0.20</td>
<td>-0.85 ± 0.21</td>
<td>0.20</td>
<td>0.00*</td>
</tr>
<tr>
<td>Time to 15 m (s)</td>
<td>6.12 ± 0.16</td>
<td>7.07 ± 0.28</td>
<td>0.95</td>
<td>0.00*</td>
</tr>
</tbody>
</table>

*Significant for p < 0.05
## Stroke Differences

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Freestyle</th>
<th>Butterfly</th>
<th>Difference in Mean</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Horizontal Distance of Max depth (m)</td>
<td>5.86 ± 0.95</td>
<td>6.68 ± 0.77</td>
<td>0.82</td>
<td>0.00*</td>
</tr>
<tr>
<td>Max Depth of Head (m)</td>
<td>-0.91 ± 0.21</td>
<td>-1.12 ± 0.22</td>
<td>0.21</td>
<td>0.01*</td>
</tr>
<tr>
<td>Total Time Underwater (s)</td>
<td>3.42 ± 0.92</td>
<td>4.52 ± 0.58</td>
<td>1.10</td>
<td>0.00*</td>
</tr>
<tr>
<td>Time to 15 m (s)</td>
<td>6.55 ± 0.54</td>
<td>6.50 ± 0.51</td>
<td>0.05</td>
<td>0.74</td>
</tr>
</tbody>
</table>

*Significant for p < 0.05
Study 3 – Key parameters of elite swimming start performance.

**Aim:** To determine the key parameters of elite start performance.

- So what is important for coaches and athletes to work on?
  - Provides a more targeted approach to biomechanics servicing.
- Same dataset as the previous study.
- Parameters were split into above-water and underwater parameters for more specific analysis.

Above-water parameters

- Parameters that occur before the swimmer enters the water.
  - Take-off horizontal velocity
Underwater Parameters

• Parameters that occur after the swimmer enters the water.
  ✓ Time to 10 m
  ✓ Time underwater in descent
  ✓ Time underwater in ascent
    ➢ Timing of first kick
    ➢ Time of Maximum Depth
    ➢ Horizontal distance of Maximum Depth
Study 4 – Do swimmers always perform better using their preferred technique?

Aim: To determine if swimmers will always perform fastest using their preferred technique?
- It was previously thought this type of comparative study design was flawed.
The swimmers were tested on four different dive trajectories.
Results

Our study found that swimmer’s will not always favour their preferred technique.
- 7 performed better with a different technique
- 2 were the same as preferred

<table>
<thead>
<tr>
<th>Dive Condition</th>
<th>Number of Swimmers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preferred</td>
<td>5</td>
</tr>
<tr>
<td>Preferred/Dive 2*</td>
<td>2</td>
</tr>
<tr>
<td>Dive 1</td>
<td>2</td>
</tr>
<tr>
<td>Dive 2</td>
<td>3</td>
</tr>
<tr>
<td>Dive 3</td>
<td>2</td>
</tr>
</tbody>
</table>

*Fastest dive was the same for both conditions
Study 5 – Comparing three underwater trajectories

**Aim:** To compare three underwater trajectories of the elite swimming start.
- These trajectories were determined from the previous studies.

14 Subjects (11 M, 3 F)
12 dives performed over two testing sessions
Three dive types → Dive 1, Dive 2, Dive 3
All elite freestylers
## Results

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Dive 1</th>
<th>Dive 2</th>
<th>Dive 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max Depth (m)</td>
<td>-0.74 ± 0.14</td>
<td>-0.92 ± 0.16</td>
<td>-1.03 ± 0.18</td>
</tr>
<tr>
<td>Distance of first kick (m)</td>
<td>6.16 ± 0.57</td>
<td>6.62 ± 0.68</td>
<td>6.65 ± 0.69</td>
</tr>
<tr>
<td>Time of First Kick (s)</td>
<td>1.96 ± 0.19</td>
<td>2.08 ± 0.24</td>
<td>2.09 ± 0.24</td>
</tr>
<tr>
<td>Time to 5 m (s)</td>
<td>1.54 ± 0.09</td>
<td>1.53 ± 0.08</td>
<td>1.53 ± 0.09</td>
</tr>
<tr>
<td>Avg. Vel. 5 -7.5 m (m.s⁻¹)</td>
<td>2.41 ± 0.24</td>
<td>2.60 ± 0.23</td>
<td>2.67 ± 0.25</td>
</tr>
<tr>
<td>Time to 15 m (s)</td>
<td>6.62 ± 0.40</td>
<td>6.54 ± 0.37</td>
<td>6.56 ± 0.42</td>
</tr>
</tbody>
</table>
Implications of Findings

• The ideal underwater trajectory is a trade-off between time spent underwater and the maintenance of velocity generated during the first two phases of the start.
• Using a shallower trajectory will increase the resistance acting on the swimmer resulting in a reduction of velocity during the underwater phase.
• Swimmers should hold their glide for longer and commence their first kick after 6.6 m.
• More research needed.
**Study 6 – How does drag affect the underwater phase of the swimming start?**

**Aim:** To quantify the amount of drag during the underwater phase of the swimming start.

Full body laser scanned prior to towing
12 Tows:
- 3 depths → Surface, 0.5 m and 1.0 m below
- 4 speeds → 1.6, 1.9, 2.0, 2.5
- Swimmers were towed in the streamline position
- Drag and wave drag was then calculated using Matlab.

Results

Average Total Drag

- 1.0 m
- 0.5 m
- Surface

Average Wave Drag

- 1.0 m
- 0.5 m
- Surface
Results

Percentage Decrease in Total Drag from the Surface

Percentage Decrease in Wave Drag from the Surface

Decrease in Drag Force (%) vs. Velocity (m·s\(^{-1}\)) for different surface heights.
Bringing it all together
Travel at least 0.5 m below the surface

Hold glide for 2 s

Max depth between 0.9 – 1.0 m

Start first kick after 6.5 m

Breakout at 10.5 m
**Study 7 – Can biomechanical feedback be used to change the underwater trajectory of the swimming start?**

**Aim:** To determine if biomechanical feedback can be used as a tool to improve start performances.

- Intervention study – 3 AIS Swimmers over 6 weeks.
- Each swimmer was given 1 key parameter to work on for the 6 week period.
### Parameter
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distance of first kick (m)</td>
<td>Digitised as the distance of the centre of the swimmer’s head at the commencement of their first underwater kick upon entry.</td>
<td>$6.62 \pm 0.68$</td>
</tr>
<tr>
<td>Breakout Distance (m)</td>
<td>The distance at which the swimmer’s head breaks the surface of the water for the first time.</td>
<td>$10.50 \pm 1.41$</td>
</tr>
<tr>
<td>Maximum Depth (m)</td>
<td>The distance the swimmer’s head reaches at maximum depth.</td>
<td>$-0.92 \pm 0.16$</td>
</tr>
</tbody>
</table>

- 2 Swimmers worked on breakout distance
- 1 Swimmer worked on distance of first kick
Precise Biomech Feedback

“Your breakout distance was 11.0 m I need you to be 0.5 m earlier on the next one”
Faded Feedback Schedule

- 78 Intervention Trials
- Absolute feedback – 43
- Relative feedback – 55%
Results

A. Mean and SD - Breakout Distance (Participant 1)

B. Mean and SD - Time to 15 m (Participant 1)
Implications of Findings

• Biomechanical feedback can be used as an effective tool to alter start performance.
• Individualised approaches to technique improvement using biomechanical feedback should be considered more in the future, particularly with elite athletes.
• Sport Scientists and Coaches should be careful not to overload athletes when providing feedback.
Practical Applications

• There is a lot that can be done during the underwater phase to reduce deceleration.
• Biomechanical feedback can be useful for improving technique if used properly.
• For the greatest improvements in swimming technique use a multi-disciplinary approach.
Practical Applications

- Biomechanics
- Hydrodynamics
- Swimming Starts
- Skill Acquisition
Take-Home Messages

• Swimmers will spend the longest amount of time in the underwater phase.
• The fastest starters are the ones that can maintain the highest velocity for the longest.
• Keep it simple.
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Thank You