Swimming performance and monitoring training with new technologies

Bjørn Harald Olstad
The framework:

**Swimming performance and monitoring training with new technologies**

1. Race analysis (video cameras with automatic movement recognition)
2. Velocity, force and power, and drag (portable winch system and a land strength system)
3. Muscular activation (surface electromyography)

Daily / live monitoring and feedback on
4. Stroke kinematics (inertial measurement units)
5. Heart rate (optical heart sensors)
Performance determining factors


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Technological possibilities

Race analysis technology

Above water cameras.

Underwater cameras placed behind windows.

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Race analysis technology

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Parameters analyzed during race analysis

\[\text{Swimming race} \rightarrow \text{Free swimming} \rightarrow \text{Stroke rate, Stroke length, Velocity} \rightarrow \text{Skills} \rightarrow \text{Start, Turns, Finish}\]

\[\text{Figure 12.3} \quad \text{Broad-level race components.}\]

How to utilize race analysis

Segment contribution
• Identifying the contribution of each segment to the finishing time
# The contribution of each segment to the finishing time

<table>
<thead>
<tr>
<th>Segment</th>
<th>Men 100-m SC breaststroke</th>
<th>Men 50-m SC butterfly</th>
<th>Women 50-m SC front crawl</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Tot. sec</td>
<td>Contribution %</td>
<td>Tot. sec</td>
</tr>
<tr>
<td>Start</td>
<td>6.89 ± 0.21</td>
<td><strong>11.23 ± 0.23</strong></td>
<td>6.28 ± 0.29</td>
</tr>
<tr>
<td>Clean swimming</td>
<td>23.95 ± 0.43</td>
<td><strong>39.00 ± 0.39</strong></td>
<td>8.48 ± 0.36</td>
</tr>
<tr>
<td>Turns</td>
<td>27.29 ± 0.25</td>
<td><strong>44.46 ± 0.54</strong></td>
<td>7.92 ± 0.37</td>
</tr>
<tr>
<td>Finish</td>
<td>3.26 ± 0.11</td>
<td><strong>5.31 ± 0.12</strong></td>
<td>2.61 ± 0.15</td>
</tr>
<tr>
<td>Break time start + turns</td>
<td>23.56 ± 1.16</td>
<td><strong>38.39 ± 2.09</strong></td>
<td>8.70 ± 1.37</td>
</tr>
</tbody>
</table>

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How to utilize race analysis

Segment contribution
• Identifying the contribution of each segment to the finishing time

Component contribution
• Identifying which segments and underlying components determines the performance
Components determining the performance

Men's 100-m short-course breaststroke

A nearly perfect correlation for 15-m start time with finishing time (.943**)
  Large negative correlation between 0-5 m time with 15-m start time (-.600)
  Moderate negative correlation between 5-10 m time with 15-m start time (-.371)
  Nearly perfect negative correlation between 10-15 m time with 15-m start time (-.943**)

10-15 m appears to be the most crucial part of the starting segment
  • Peak velocity showed a very large correlation 10-15 m time (.821*)
    • Peak velocity range 2.06-2.44 m/s, generated from the underwater arm pull = crucial
Components determining the performance

Men's 50-m short-course butterfly (start and turn performance)

- Mean underwater kick velocity has a large impact on the 15 m start and 10 m turn time
- First kick velocity is essential for the mean underwater kick velocity during the start
- Last kick velocity is important for the mean underwater kick velocity during the turn
Components determining the performance

Men's 1500-m short-course front crawl (turn and swimming performance)
Investigated 1st-2nd-3rd-6th place finisher at the World Championship, Hangzhou 2018

**Turn**: 5-m before the wall to 5-m after the wall can significantly affect the overall ranking

#2 and 6 had significant losses in time during the turn
#3 the slowest swimmer, but made third place due to the turn performance
How to utilize race analysis

Segment contribution
- Identifying the importance of each segment to the finishing time

Component contribution
- Identifying which components determining the performance

Race modelling
- Compare yourself to the "gold standard" / others / yourself
- Identifying strengths and weaknesses
## Race modelling

<table>
<thead>
<tr>
<th></th>
<th>Reaction time</th>
<th>Leaving the block to 15 M</th>
<th>Free swim 15-20 M</th>
<th>5 M to wall</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fastest swimmer</td>
<td>0.68</td>
<td>6.06</td>
<td>3.12</td>
<td>2.79</td>
</tr>
<tr>
<td>Fastest time</td>
<td>0.63</td>
<td>6.06</td>
<td>3.12</td>
<td>2.67</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>5 M to wall</th>
<th>Free swim 35-45 M</th>
<th>Wall to 10 M</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pivot time 0.98</td>
<td>2.85</td>
<td>6.61</td>
<td>4.87</td>
</tr>
<tr>
<td>Pivot time 0.70</td>
<td>2.79</td>
<td>6.45</td>
<td>4.87</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Wall to 10 M</th>
<th>Free swim 60-70 M</th>
<th>5 M to wall</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.03</td>
<td>6.88</td>
<td>2.96</td>
</tr>
<tr>
<td>4.94</td>
<td>6.64</td>
<td>2.96</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>5 M Finish</th>
<th>Free swim 85-95 M</th>
<th>Wall to 10 M</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.15</td>
<td>7.17</td>
<td>5.30</td>
</tr>
<tr>
<td>3.13</td>
<td>7.03</td>
<td>5.30</td>
</tr>
</tbody>
</table>

Green within 0.00-0.099 s, Yellow within 0.10-0.199 s, Red over 0.20 s slower than the best performance

**Swimming performance and monitoring training with new technologies**

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How to utilize race analysis

Segment contribution
• Identifying the importance of each segment to the finishing time

Component contribution
• Identifying which components determining the performance

Race modelling
• Comparing yourself to the gold standard
• Identifying strengths and weaknesses

Compare after training
• If the training improved your specific performance criteria
## Compare after training

### 50-m front crawl: Left / right stroke distance

#### At testing

<table>
<thead>
<tr>
<th>Lap</th>
<th>Avg. distance left arm</th>
<th>Avg. distance right arm</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.05</td>
<td>0.99</td>
</tr>
<tr>
<td>2</td>
<td>1.02</td>
<td>0.95</td>
</tr>
</tbody>
</table>

#### After

<table>
<thead>
<tr>
<th></th>
<th>Avg. distance left arm</th>
<th>Avg. distance right arm</th>
</tr>
</thead>
<tbody>
<tr>
<td>After 1</td>
<td>1.04</td>
<td>1.03</td>
</tr>
<tr>
<td>After 2</td>
<td>1.03</td>
<td>1.04</td>
</tr>
</tbody>
</table>
Future direction

Start and turns

Implementation of Inertial Measurement Units

The effect of training on race analysis parameters and performance
Inertial Measurement Units (IMU's)


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https://www.myon.ch/aktos-t

Weight: 5.3 g
Dimensions: 32.7 x 25.5 x 7.8 mm
Be aware of

Working with IMUs in an aquatic environment is not as straightforward as it might appear

• Attach and seal sensors (deMagalhães et al., 2014)

• Sensor may be cumbersome (on average 50 x 35 x 15 mm between 2013 and 2015, Mooney et al., 2015)

• Relative movement between sensor and body segment (Fong and Chan, 2010)

• Can modify the swimming pattern and increase drag (James et al., 2011; Dadashi et al., 2013)

• Sensor position must not disturb swimmers’ interactions with the water (Bächlin and Tröster, 2011)

• Drift (Woyano et al., 2016)
On the market

http://www.tritonwear.com/

Stroke type
Split time – CV>5%
Speed – CV>6%
Stroke count – CV>5%
Stroke rate – CV>5%
Pace time
SWOLF

Distance per stroke CV=14.64% FC
Time underwater CV=18.2% FC, 25.8% BR
Turn times CV=10.4%, FC 12.9% BR

Breath count
Push-Off strength
Stroke index

Audio feedback

http://www.avidasports.com/

Tempo
Stroke Count
Breakout
Distance per Stroke
Average Speed
Split Times
Kick Count
Kick Tempo

http://www.xmetrics.it

Workout time
Distance swam
Lap time and count
Rest and split time
Pace
Stroke count
Stroke frequency
Stroke rate
Distance per stroke
Stroke Index Efficiency
Turn total time
Breath count
Style detection
SWOLF Index
Interval detection
Calories burned

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Swimming performance and monitoring training with new technologies

doi.org/10.1051/mms/2019027
SwimBIT

Based on attitude and heading reference system (AHRS) and a machine learning workflow for data analysis

Three novel indicators are measured:

**Body Rotation**: Body roll angle (longitudinal)
- Front crawl / backstroke: poor body rotation, excessive rotation and asymmetrical rotation
- Breaststroke / butterfly, the average rotation of the swimmer's body during a given lap (close to 0°)

**Trunk Elevation**: The elevation angle of the trunk in butterfly and breaststroke
- Undulation, the difference between the minimum and maximum pitch angles within a stroke cycle; the average trunk elevation per lap

**Body Balance**: Pitch angle
- Front crawl / backstroke should be fairly horizontal and constant towards 0°
How to utilize IMU's

The missing piece to swim coaching – **instantaneous feedback** on stroke metrics

- Track the swimmers through daily training (continuous data over long periods)
- Provide the coach and swimmer with a much more detailed analysis of every work-out
- Identifying if you work on and improve the focus points from race analysis or for the training

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Future direction

Integrate with race analysis to acquire additional parameters such as:

Instantaneous velocity

Swimmers’ joint angles, today the process to do so is both laborious and error prone
Strength & power – land and water technology

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Swimmers have changed

It's clear that today's top-level swimmers are more powerful and look physically stronger than ever before!

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https://myswimpro.com/blog/2016/05/24/dramatic-changes-in-swimmers-physiques-over-the-past-century/
and also the view on strength training

Methods 1980 (selection):
• Development of strength-endurance is crucial for landtraining
• Usage of swimming benches
• Movement velocity during strength training should be the same as during competition
• 1 RM muscle contraction with unspecific velocity is not meaningful
• (Low maximal-)strength requirements in swimming
• High force peaks are not necessary for propulsion

Strength training for the development of maximal strength is basic
Methods with high to very high loads

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Strength training can improve the performance during starts and turns.

**Requirement for Olympic Games final:**

**Squat Jump**

<table>
<thead>
<tr>
<th>Event</th>
<th>Men</th>
<th>Women</th>
</tr>
</thead>
<tbody>
<tr>
<td>50 m front crawl</td>
<td>&gt; 45 cm</td>
<td>&gt; 40 cm</td>
</tr>
<tr>
<td>100 m front crawl</td>
<td>&gt; 45 cm</td>
<td>&gt; 40 cm</td>
</tr>
<tr>
<td>200 m front crawl</td>
<td>&gt; 40 cm</td>
<td>&gt; 35 cm</td>
</tr>
<tr>
<td>400 m front crawl</td>
<td>&gt; 40 cm</td>
<td>&gt; 35 cm</td>
</tr>
<tr>
<td>800 m front crawl</td>
<td></td>
<td>&gt; 30 cm</td>
</tr>
<tr>
<td>1500 m front crawl</td>
<td>&gt; 35 cm</td>
<td></td>
</tr>
<tr>
<td>100 m butterfly</td>
<td>&gt; 45 cm</td>
<td>&gt; 40 cm</td>
</tr>
<tr>
<td>200 m butterfly</td>
<td>&gt; 40 cm</td>
<td>&gt; 35 cm</td>
</tr>
<tr>
<td>100 m breaststroke</td>
<td>&gt; 45 cm</td>
<td>&gt; 40 cm</td>
</tr>
<tr>
<td>200 m breaststroke</td>
<td>&gt; 40 cm</td>
<td>&gt; 35 cm</td>
</tr>
<tr>
<td>100 m backstroke</td>
<td>&gt; 45 cm</td>
<td>&gt; 40 cm</td>
</tr>
<tr>
<td>200 m backstroke</td>
<td>&gt; 40 cm</td>
<td>&gt; 35 cm</td>
</tr>
</tbody>
</table>
How strong is strong enough?

Frequently observed 1rep max scores on key exercises in elite senior swimmers

<table>
<thead>
<tr>
<th>Gender</th>
<th>Distance</th>
<th>Chin Up (BW + kg)</th>
<th>Bench Press (kg)</th>
<th>Back Squat (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female</td>
<td>Sprint</td>
<td>25</td>
<td>75</td>
<td>85</td>
</tr>
<tr>
<td></td>
<td>Middle</td>
<td>20</td>
<td>65</td>
<td>80</td>
</tr>
<tr>
<td></td>
<td>Distance</td>
<td>15</td>
<td>55</td>
<td>75</td>
</tr>
<tr>
<td>Male</td>
<td>Sprint</td>
<td>50</td>
<td>120</td>
<td>130</td>
</tr>
<tr>
<td></td>
<td>Middle</td>
<td>35</td>
<td>100</td>
<td>115</td>
</tr>
<tr>
<td></td>
<td>Distance</td>
<td>30</td>
<td>90</td>
<td>100</td>
</tr>
</tbody>
</table>

BW = Body Weight

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How to utilize the technology

Force-velocity or load-velocity profiles can be used for describing different movements

Can be used to assess an athlete’s force (load) and velocity production capabilities – and therefore if an athlete is force/load or velocity dominated


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Semi-tethered swimming

1080 Sprint
Starting block

Predicting and assessing swimming performance

\[ V_{adj} \text{, adjusted horizontal velocity; } V_0 \text{, predicted maximum velocity; } L_0 \text{, predicted maximum load} \]
Load-velocity: Reliability front crawl swimming

ICC > 0.9 being defined as excellent agreement and CV < 5% for most variables, during both five and three trials analysis.

Standard error of measurement (SEM) was rated as “good” compared to Minimal detectable change (MDC) for all variables during both five and three trials analysis.
Predicting performance: Male swimmers in 50-m butterfly

The relationship between the predicted maximum speed from the load-velocity slope ($V_0$) and the maximum speed during 50 m swimming ($V_{max}$)

There was a very large correlation ($r=0.885$, $p<0.001$) and a high intra-class correlation 0.844, $p<0.001$ between the race velocity and the predicted maximum velocity.
Performance measurements

Correlation coefficients between variables obtained from load-velocity and 50m swimming

<table>
<thead>
<tr>
<th></th>
<th>L₀</th>
<th>rL₀</th>
<th>V₀</th>
<th>Slope</th>
</tr>
</thead>
<tbody>
<tr>
<td>V₅₀FC</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>V₅₀BF</td>
<td>0.556*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0.885**</td>
<td></td>
</tr>
</tbody>
</table>

Correlation coefficients between variables obtained from load-velocity (girls 11-13-16 yrs)

<table>
<thead>
<tr>
<th></th>
<th>L₀</th>
<th>rL₀</th>
<th>V₀</th>
<th>Slope</th>
</tr>
</thead>
<tbody>
<tr>
<td>V₀FC</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>V₀BA</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>V₀BR</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>V₀BF</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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Load-velocity: Elite male swimmers in 50-m butterfly
How to utilize the technology

(Peak) power training

![Graph showing the relationship between force, velocity, and power.](image)

<table>
<thead>
<tr>
<th>$L_0$</th>
<th>$v_{max}$</th>
<th>Slope</th>
<th>$L_{opt}$</th>
<th>$v_{opt}$</th>
<th>$L_{dec10%}$</th>
<th>$v_{dec10%}$</th>
<th>$R^2_{adjusted}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>22.90</td>
<td>1.53</td>
<td>-0.07</td>
<td>11.45</td>
<td>0.76</td>
<td>2.29</td>
<td>1.28</td>
<td>0.994</td>
</tr>
</tbody>
</table>

Figure 2 – Graphic display of linear force-velocity relationship & polynomial power-velocity relationship (Cross et al. 2017)

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How to utilize the technology

"Power curve"

Breaststroke girls
How to utilize the technology

Breathing and asymmetries

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How to utilize the technology

Passive drag (active)
Future direction

Further establish relationships between load-velocity parameters and swimming performance

Is there an optimal load-velocity relationship for different strokes and distances?

Lower and upper body contribution

Active drag??
Heart rate in swimming

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How accurate is optical heart rate?

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How accurate is optical heart rate?

Table 1. Descriptive statistics of the three different devices.

<table>
<thead>
<tr>
<th></th>
<th>H10</th>
<th>OH1</th>
<th>M600</th>
<th>Effect size</th>
<th>ICC</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>HRmax [bpm]</td>
<td>188.9±12.0</td>
<td>188.1±12.1</td>
<td>178.4±16.4</td>
<td>.175</td>
</tr>
<tr>
<td></td>
<td>HRmean [bpm]</td>
<td>140.6±11.0</td>
<td>139.5±11.8</td>
<td>131.1±11.2</td>
<td>.207</td>
</tr>
<tr>
<td></td>
<td>HRmin [bpm]</td>
<td>75.3±10.5</td>
<td>74.4±10.6</td>
<td>75.8±12.3</td>
<td>.069</td>
</tr>
</tbody>
</table>

a: significantly different to H10 (p < 0.05), 
b: significantly different to OH1 (p < 0.05), 
*: significant correlation with H10 (p < 0.05)

Abbreviations: HR=heart rate; bpm=beats per minute; ICC=intra-class correlation coefficient
How accurate is optical heart rate?

Table 2. Percentage distribution of the training heart rates with respect to the maximal heart rate measured by the particular device.

<table>
<thead>
<tr>
<th>of HRmax</th>
<th>H10</th>
<th>OH1</th>
<th>M600</th>
<th>Effect size</th>
<th>ICC</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>H10–OH1</td>
<td>H10–M600</td>
<td>H10–OH1</td>
<td>H10–M600</td>
</tr>
<tr>
<td>91–100%</td>
<td>15.0±5.2</td>
<td>13.6±6.0</td>
<td>8.9±5.2 a,b</td>
<td>.018</td>
<td>.591</td>
</tr>
<tr>
<td>81–90%</td>
<td>23.0±6.9</td>
<td>22.2±7.7</td>
<td>22.2±10.0</td>
<td>.088</td>
<td>.112</td>
</tr>
<tr>
<td>71–80%</td>
<td>24.7±8.1</td>
<td>25.3±9.4</td>
<td>28.5±9.2</td>
<td>.021</td>
<td>.136</td>
</tr>
<tr>
<td>61–70%</td>
<td>17.7±5.2</td>
<td>19.3±6.3</td>
<td>23.8±8.6 a,b</td>
<td>.139</td>
<td>.353</td>
</tr>
<tr>
<td>51–60%</td>
<td>12.4±7.5</td>
<td>13.0±7.8</td>
<td>12.3±9.9</td>
<td>.037</td>
<td>.000</td>
</tr>
<tr>
<td>&lt;50%</td>
<td>7.2±5.2</td>
<td>6.6±4.7</td>
<td>4.3±3.8 a,b</td>
<td>.200</td>
<td>.269</td>
</tr>
</tbody>
</table>

a: significantly different to H10 (p < 0.05),
b: significantly different to OH1 (p < 0.05),
*: significant correlation with H10 (p < 0.05)

Abbreviations: HR–heart rate; ICC–intra-class correlation coefficient
How to utilize heart rate

Monitoring intensity / training load:

• VO₂max (calculate velocities)
• Lactate (calculate velocities)
• Step-test, Critical Swim Speed (calculate velocities)
• Heart rate (% of maxHR)
• RPE (subjective)

Swim training is predominantly based on velocity (from lactate, step-tests and Critical Swim Speed)

• Continuously monitor training intensity
• Teaching intensity control

• Maximal heart rate land and water
• Protocol for achieving maximal heart rate in swimming

### Intensity zone

<table>
<thead>
<tr>
<th>Intensity zone</th>
<th>% of VO₂max</th>
<th>% of HRmax</th>
<th>Lactate (KDK)</th>
<th>Total duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>l-zone 8</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>1 – 3 min</td>
</tr>
<tr>
<td>l-zone 7</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>3 – 6 min</td>
</tr>
<tr>
<td>l-zone 6</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>6 – 15 min</td>
</tr>
<tr>
<td>l-zone 5</td>
<td>94 – 100</td>
<td>92 – 97</td>
<td>6.0 – 10.0</td>
<td>15 – 30 min</td>
</tr>
<tr>
<td>l-zone 4</td>
<td>87 – 94</td>
<td>87 – 92</td>
<td>4.0 – 6.0</td>
<td>30 – 50 min</td>
</tr>
<tr>
<td>l-zone 3</td>
<td>80 – 87</td>
<td>82 – 87</td>
<td>2.5 – 4.0</td>
<td>50 – 90 min</td>
</tr>
<tr>
<td>l-zone 2</td>
<td>65 – 80</td>
<td>72 – 82</td>
<td>1.5 – 2.5</td>
<td>1 – 3 h</td>
</tr>
<tr>
<td>l-zone 1</td>
<td>45 – 65</td>
<td>60 – 72</td>
<td>0.8 – 1.5</td>
<td>1 – 6 h</td>
</tr>
</tbody>
</table>
Maximal Heart Rate for Elite Swimmers

• Different protocol to achieve maximal heart rate (maxHR) in sprinters compared to middle-distance swimmers?
• To determine the difference in maxHR between front crawl swimming and running/cycling
  • Three different maxHR step-test protocols
  • MaxHR test in running/cycling

2.3.2. Test Protocol for Land Measurements

A velocity and inclination ramp test was performed on the treadmill with a pre-defined increase in speed (2 min at 8.5 km·h⁻¹, and then a rise of 1.5 km·h⁻¹ every 30 s up to 14.5 km·h⁻¹) and thereafter inclination (0.5° every 30 s) [22].

The cycling step-test began with a workload of 60 watts and then increased by 30 watts every minute until exhaustion [23]. The protocols were selected based on the predicted abilities of the participants. Moreover, a steady increase in load during an incremental test (every 30–60 s) allows the cardiopulmonary system to respond gradually [24].
Maximal Heart Rate for Elite Swimmers

- Different protocol to achieve maximal heart rate (maxHR) in sprinters compared to middle-distance swimmers?
- To determine the difference in maxiHR between front crawl swimming and running/cycling
- Three different maxHR protocols: 50 m, 100 m and 200 m step-test protocol
  - MaxHR test in running/cycling
- No differences in maxHR between the 200 m (mean ± SD; 192.0 ± 6.9 bpm), 100 m (190.8 ± 8.3 bpm) or 50 m protocol (191.9 ± 8.4 bpm).
- No differences in maxHR between sprinters and middle-distance for swimming protocols
- MaxHR was 6.7 ± 5.3 bpm lower for swimming compared to running (199.9 ± 8.9 bpm for running)
- All step-test protocols were suitable for achieving maxHR during front crawl swimming
- No separate protocol is needed for swimmers specialized in sprint or middle-distance
- Important to conduct sport-specific maxHR tests for different sports that are targeted to improve the aerobic capacity among elite swimmers of today (triathletes)
Surface electromyography (sEMG)

Weight: 7.9 g
Dimensions: 32 x 17 x 12 mm

https://www.myon.ch/aktos

Swimming performance and monitoring training with new technologies
Bjørn Harald Olstad
How to utilize sEMG

Recommendations from sEMG and kinematics for evaluating breaststroke technique:

• An early activation in biceps femoris during leg recovery in order to decrease the time spent in this phase.
• A late and quick activation in tibialis anterior during leg recovery in order to reduce drag and premature dorsiflexion of the foot.
• An early activation in biceps brachii in the arm pull for elbow flexion in order to generate earlier arm propulsion and a more continuous stroke pattern at maximal effort.
• An active use of gastrocnemius during the gliding phase to maintain a more streamlined position of the feet.
• Activation in rectus femoris during the beginning of the gliding phase for full knee extension to occur after the feet insweep. This might point to an active strategy for performing body undulation.
• An earlier and longer pectoralis major activation during the leg recovery phase (arm propulsive phase) to "grab" the water earlier and generate higher forward propulsion from the arm pull and use a more continuous coordination mode.
• An activation in trapezius during the leg kick phase in order to maintain upper body streamline position.
• Creation of a small knee angle during the beginning of leg propulsion (leg kick phase) in order to generate a longer propulsive path for the leg kick.
• Avoidance of excessive coactivation in tibialis anterior and gastrocnemius during the stroke cycle, and excessive use of triceps brachii during the leg kick phase (non-propulsive arm phase), which may cause an earlier onset of muscular fatigue during training and competition.
How to utilize sEMG

- Muscle is active or not
- How active is the muscle
- Co-activation

Figure 4. Average muscle activation (avgC) pattern during breaststroke swimming at 66-90-100% of maximal effort for the four muscles of the upper limb during the three phases of the complete stroke cycle. Amplitude is normalised to the relative maximal voluntary contraction (MVC) and duration is normalised to the stroke cycle (%). --- 60%; --- 80%; --- 100% Muscle onset and offset are determined from the avgC pattern using an EMG threshold value fixed at 20% of the peak EMG recorded during the cycle (horizontal line). Vertical lines represent the duration of the respective phases in % of the total stroke cycle. (A) TB – triceps brachii, (B) BB – biceps brachii, (C) TPA – trapezius (pars descendens) and (D) PM – pectorals major (pars clavicularis).
How to utilize sEMG

Muscular correspondence between maximal effort and technique and drill exercises

When the muscles on the upper body was activated

When the muscles on the lower body was activated
Future direction

- Intermuscular coordination and movement economy
- Muscular activation in Paralympic swimmers
- Muscular fatigue during middle-distance and long-distance events
- Asymmetries
Future technologies

Instrumented starting block and turning plate

Pressure sensors

3D motion analysis

Oxygen consumption

Pacing lane lines
Thank you for your attention!

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