Diagnostic of rowing performance and technique to optimise the rowing technique

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Structure

1. How can we test the rowing technique with the help of biomechanical methods?
2. How can we interpret the biomechanical data?
3. Biomechanical feedback in the racing boat
Final Race, London 2012
Drive CZE
forward position
end of drive

Drive NZL
catch
feathering, finish position
The current mobile measuring and training system
Final women’s quadruple scull
German Championships Berlin,
June 2004

Overview of the athletes, women, n=8

<table>
<thead>
<tr>
<th>Place</th>
<th>time [s]</th>
<th>number of strokes</th>
<th>SR [1/min]</th>
<th>bh [m]</th>
<th>bm [kg]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Second</td>
<td>427.1</td>
<td>240.6</td>
<td>33.8±1.3</td>
<td>1.81 ±0.05</td>
<td>72.0 ±4.54</td>
</tr>
<tr>
<td>n=4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Winner</td>
<td>425.4</td>
<td>234.7</td>
<td>33.1±1.7</td>
<td>1.80 ±0.04</td>
<td>71.5 ±5.04</td>
</tr>
<tr>
<td>n=4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Total evaluation, 2000m

\[ \sum W_{\text{handle}}/t_{2000m} \quad [W] \]

- **Winner**: 253 ± 16 W
- **Second**: 263 ± 29 W
Comparison winner vs. second place, race time difference < 2s

<table>
<thead>
<tr>
<th></th>
<th>Handle power</th>
<th>Handle work</th>
<th>Handle force</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>[W]</td>
<td>[J]</td>
<td>[N]</td>
</tr>
<tr>
<td>Winner, n=4</td>
<td>294</td>
<td>226</td>
<td>152</td>
</tr>
<tr>
<td>Second, n=4</td>
<td>320</td>
<td>238</td>
<td>165</td>
</tr>
</tbody>
</table>

- Handle power: [W]
- Handle work: [J]
- Handle force: [N]
Comparison winner and second place, German Championships 2004, W4x
What can we emphasize?

- Rowing technique is an important factor of rowing performance.
- It transfers the physical abilities in rowing performance.
- The quality of rowing technique in the drive and recovery effect the race result that is expressed in the curves of the rowing technique.
- For the crew it is reflected in the acceleration curve of the boat.
- The handle power is only a necessary but not a sufficient condition for fast rowing.
- Rowing technique must satisfy scientific criteria!
- Success in competition is not a scientific criterion!
- Individual characteristics of internationally successful rowing teams are often misinterpreted as a further development of rowing technique.
Structure

1. How can we test the rowing technique with the help of biomechanical methods?
2. How can we interpret the biomechanical measuring results?
3. Biomechanical feedback in the racing boat
Rowing technique

…is a biomechanically and physiologically performance-effective solution to the specific task in sculling or sweep rowing, to transfer the physiological and anthropometric capabilities of the athlete via the oar to the boat in such a way that by making maximum use of external conditions and in the prevailing tactical situation a high average speed of the combined boat/athlete system results (Mattes, 2006, p.55).
Rowing technique

Sculling technique

Sweep rowing technique
Sculling technique

the same solution for the rowing task, but of course with individual differences
Rowing technique

depends on

– different biomechanical properties of the human musculoskeletal system (strength, endurance, flexibility…)
– tasks in training and racing (i.e. different stroke rates and boat velocity)
– boat class (varying boat velocity and corresponding water resistances)
– oar adjustments (gear ratio, blade shapes and surfaces)
– gender specific, junior training
Rowing technique

Rowing technique can be measured via kinematic and dynamic parameters and characteristic curves.

characteristic curves

characteristic values

\[ F_{\text{max}} = 810 \, \text{N} \]
\[ F_{\text{mean}} = 600 \, \text{N} \]
\[ t_{\text{drive}} = 0.72 \, \text{s} \]
Applied forces on a boat

-\text{ma}^b = \text{inertial force}

\text{m} = \text{mass}

\text{a}^b = \text{boat acceleration}

\vec{F}^b = \text{net boat force}

\vec{F}_{\text{gate}} = \text{gate force}

\vec{F}_{\text{seat}} = \text{seat force}

\vec{F}_{\text{st}} = \text{stretcher force}

\vec{F}_{\text{air}} = \text{total air drag force}

\vec{F}^W = \text{total hydrodynamic drag force}

\vec{F}^b = \vec{F}_{\text{gate}} + \vec{F}_{\text{st}} + \vec{F}_{\text{seat}}

- \text{m} \cdot \vec{a}^b = \vec{F}^b + \vec{F}^W + \vec{F}_{\text{air}}
Applied forces on a boat

- \( \mathbf{F}^b \) = net boat force
- \( \mathbf{F}^\text{gate} \) = gate force
- \( \mathbf{F}^\text{st} \) = stretcher force
- \( \mathbf{F}^W \) = total hydrodynamic drag force
- \( \mathbf{F}^\text{air} \) = total air drag force

\(- m \cdot \mathbf{a}^b = \mathbf{F}^b + \mathbf{F}^W + \mathbf{F}^\text{air}\)

\(-m \mathbf{a}^b\) = inertial force

\( m = \) mass

\( \mathbf{a}^b = \) boat acceleration
Applied forces on a boat

recovery

\[-m \vec{a}^b = \text{inertial force}\]
\[m = \text{mass}\]
\[\vec{a}^b = \text{boat acceleration}\]

\[\vec{F}^b = \text{net boat force}\]
\[\vec{F}^{st} = \text{stretcher force}\]
\[\vec{F}^{seat} = \text{seat force}\]

\[\vec{F}^{W} = \text{total hydrodynamic drag force}\]
\[\vec{F}^{air} = \text{total air drag force}\]
Applied forces on a boat

recovery

\[-ma^b\]

\[\begin{align*}
F^b &= F^{st} \\
-m \cdot \vec{a}^b &= F^b + F^W + F^{air}
\end{align*}\]

- \(ma^b\) = inertial force
- \(m\) = mass
- \(a^b\) = boat acceleration
- \(F^b\) = net boat force
- \(F^w\) = total hydrodynamic drag force
- \(F^{air}\) = total air drag force
- \(F^{st}\) = stretcher force
Comparison of curves of boat-force ($F_{\text{boat}}$) against boat-acceleration ($a_{\text{boat}}$) using a single (1x) as an example.
Force-angle curves, four rowers, same stroke rate

F gate [N]

F stretcher [N]

F boat [N]

Angle [°]

No. 5
No. 6
No. 7
No. 8
Force-angle curves, one rower, different stroke rates

- **F_{gate} [N]**
- **F_{stretcher} [N]**
- **F_{boat} [N]**

**Seat 2 8+**

- SR 20
- SR 24
- SR 28
- SR 32
- 500 m
Force-angle curves, one rower, different stroke rates
Synchronisation of video and biomechanical data
Important aspects of rowing technique

1. Force curve represents the rower’s signature (Nolte 1979), independently of stroke frequency or the applied force (individual’s rowing technique).
2. The experienced rower has the ability to vary his/her technique in respect of force and movement speed to adapt on varying conditions.
3. There arise typical changes in rowing technique which depend on boat speed and stroke frequency.
4. Rowing technique must be tested under the different demands of training and competition to be able to form reliable conclusions.
5. The difficulty lies in clearly distinguishing the individual manifestations and drawing the right conclusions to be followed in technique training.
Structure of the rowing stroke

Rear reversal:
- Hands away
- Forward sliding
- Slowing down

Recovery

Front reversal:
- Start of drive (sd)
- Middle of drive (md)
- End of drive (ed)

Drive
Structure

1. How can we test the rowing technique with the help of biomechanical methods?
2. How can we interpret the biomechanical data?
3. Biomechanical feedback in the racing boat
Biomechanical parameters of rowing power and technique

parameters and characteristic curves

kinematic
- oar angle ($\phi$)
- oar velocity ($v_{\text{handle}}$)
- seat position ($s_{\text{seat}}$)
- seat velocity ($v_{\text{seat}}$)

individual parameter

crew parameter
- boat acceleration ($a_{\text{boat}}$)
- boat velocity ($v_{\text{boat}}$)

dynamic
- handle force ($F_{\text{handle}}$)
- gate force ($F_{\text{gate}}$)
- stretcher force ($F_{\text{stretcher}}$)
- boat force ($F_{\text{boat}}$)
Comparison of biomechanical curves for rowing technique

Ideal curves

Curves with error illustrations

\( \angle \)

\( t_{\phi_{\text{min}}} \)

\( t_{\phi_{\text{max}}} \)

\( t_{\phi_{\text{min}}} \)

\( \text{d} = \text{drive} \)

\( \text{r} = \text{recovery} \)

\( F_{\text{gate}} \)

\( F_{\text{stretcher}} \)

\( F_{\text{boat}} \)

\( v_{\text{seat}} \)

\( v_{\text{boat}} \)
Rowing angle and stroke phases

Finish position
Finish
Middle of drive
100°

70°
Start of drive

Forward position

$\varphi_{\text{min}}$
Rowing movement structure

[Diagram showing force and angle characteristics during rowing motion, with key points labeled: \( \Phi_{\text{max}} \), \( \Phi_{\text{min}} \), \( \Phi_{\text{wf}} \), \( eS_1 \), \( S_1 \), drive, recovery, \( t_B \), \( t_E \), force and angle axes labeled.]
Characteristic oar angle-time curves

ideal curves
curves with error illustrations

- rhythm ratio (1)
- steep or shallow rises mean high or low oar angular velocity (2)
- plateau indicates a stopping of the oar handle (movement pause) (3)
Characteristic seat-velocity time curves

Ideal curves

Curves with error illustrations

- unbalanced work by the legs or a stroke phase with over-emphasised start (4) or middle of the drive (5)
- start of sliding (too early or too late and/or too strongly (6)
- sternward movement (too quick or too slow) (7)
- braking (too early or too late) (8)
- flowing forward direction reversal (no pause in the seat movement) (9)
## Stroke length, stroke angles and seat position

### Senior men average values over 2000m

<table>
<thead>
<tr>
<th>Data</th>
<th>$SI [^\circ]$</th>
<th>$\varphi_i [^\circ]$</th>
<th>$\varphi_{wc} [^\circ]$</th>
<th>$t_{wc}$ [s]</th>
<th>$\varphi_x [^\circ]$</th>
<th>$\varphi_{wf}$ [^\circ]</th>
<th>$t_{wf}$ [s]</th>
<th>$S^{\text{seat cycle}}$ [m]</th>
<th>$S^{\text{seat drive}}$ [m]</th>
</tr>
</thead>
<tbody>
<tr>
<td>M1x</td>
<td>110</td>
<td>24</td>
<td>1</td>
<td>0.04</td>
<td>134</td>
<td>3</td>
<td>0.07</td>
<td>0.6</td>
<td>0.53</td>
</tr>
<tr>
<td>M2x</td>
<td>110</td>
<td>24</td>
<td>1</td>
<td>0.04</td>
<td>134</td>
<td>3</td>
<td>0.07</td>
<td>0.6</td>
<td>0.53</td>
</tr>
<tr>
<td>M4x</td>
<td>110</td>
<td>24</td>
<td>1</td>
<td>0.04</td>
<td>134</td>
<td>3</td>
<td>0.07</td>
<td>0.6</td>
<td>0.53</td>
</tr>
<tr>
<td>LM2x</td>
<td>106</td>
<td>28</td>
<td>1</td>
<td>0.04</td>
<td>134</td>
<td>3</td>
<td>0.07</td>
<td>0.54</td>
<td>0.5</td>
</tr>
<tr>
<td>M2-</td>
<td>90</td>
<td>36</td>
<td>1.5</td>
<td>0.05</td>
<td>126</td>
<td>4</td>
<td>0.09</td>
<td>0.6</td>
<td>0.54</td>
</tr>
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<td>M4-</td>
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<td>0.54</td>
</tr>
<tr>
<td>M8+</td>
<td>90</td>
<td>36</td>
<td>1.5</td>
<td>0.05</td>
<td>126</td>
<td>4</td>
<td>0.09</td>
<td>0.6</td>
<td>0.54</td>
</tr>
<tr>
<td>LM4-</td>
<td>86</td>
<td>38</td>
<td>1.5</td>
<td>0.05</td>
<td>124</td>
<td>4</td>
<td>0.09</td>
<td>0.56</td>
<td>0.5</td>
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</table>
# Stroke length, stroke angles and seat position

Senior women average values over 2000m

<table>
<thead>
<tr>
<th>Data</th>
<th>SI °</th>
<th>φᵢ °</th>
<th>φ₇c °</th>
<th>t₇c s</th>
<th>φₓ °</th>
<th>φ₇f °</th>
<th>t₇f s</th>
<th>S&lt;sub&gt;cycle&lt;/sub&gt; [m]</th>
<th>S&lt;sub&gt;drive&lt;/sub&gt; [m]</th>
</tr>
</thead>
<tbody>
<tr>
<td>unit</td>
<td>°</td>
<td>°</td>
<td>°</td>
<td>s</td>
<td>°</td>
<td>°</td>
<td>s</td>
<td>m</td>
<td>m</td>
</tr>
<tr>
<td>W1x</td>
<td>106</td>
<td>28</td>
<td>1</td>
<td>0.04</td>
<td>134</td>
<td>3</td>
<td>0.07</td>
<td>0.52</td>
<td>0.48</td>
</tr>
<tr>
<td>W2x</td>
<td>106</td>
<td>28</td>
<td>1</td>
<td>0.04</td>
<td>134</td>
<td>3</td>
<td>0.07</td>
<td>0.52</td>
<td>0.48</td>
</tr>
<tr>
<td>W4x</td>
<td>106</td>
<td>28</td>
<td>1</td>
<td>0.04</td>
<td>134</td>
<td>3</td>
<td>0.07</td>
<td>0.52</td>
<td>0.48</td>
</tr>
<tr>
<td>LW2x</td>
<td>102</td>
<td>30</td>
<td>1</td>
<td>0.04</td>
<td>132</td>
<td>3</td>
<td>0.07</td>
<td>0.48</td>
<td>0.44</td>
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<tr>
<td>W2-</td>
<td>86</td>
<td>36</td>
<td>1.5</td>
<td>0.05</td>
<td>122</td>
<td>4</td>
<td>0.09</td>
<td>0.5</td>
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</tr>
<tr>
<td>W8+</td>
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<td>36</td>
<td>1.5</td>
<td>0.05</td>
<td>122</td>
<td>4</td>
<td>0.09</td>
<td>0.5</td>
<td>0.46</td>
</tr>
</tbody>
</table>
Synchronisation of video and biomechanical data
Handle and gate force

- $F_{ht}$: handle-force
- $F_{hn}$: normal component
- $F_{hl}$: longitudinal component
- $\phi_{Fh}$: angle of pull direction
- $F_{gt}$: gate-force
- $F_{gn}$: normal component
- $F_{gl}$: longitudinal component
- $F_{st}$: stretcher-force
- $F_{stn}$: normal component
- $F_{stt}$: transverse component
- $F_{bl}$: blade-force

Inboard, handle, gate, blade.
Characteristic handle force-time curves

ideal curves  curves with error illustrations

• complete characterisation of the pattern of the stroke structure
  – in idealised form (10)
  – or with emphasis on the start (11)
  – or the middle (12)
  – or the finish of stroke (13).

• the variation of force dynamics with time
  – at the beginning or the end of the drive (14)
  – force increase (15),
  – magnitude of the applied force (16)

• air shot at the catch (17)
• length of the finish (18)
• sharpness and speed of extraction (19)
## Typical values of the handle power and its components

Senior men on average over 2000m

<table>
<thead>
<tr>
<th>Data</th>
<th>cycle</th>
<th>drive</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>bh</td>
<td>SR</td>
</tr>
<tr>
<td>unit</td>
<td>m</td>
<td>1/min</td>
</tr>
<tr>
<td>M1x</td>
<td>1.96</td>
<td>37</td>
</tr>
<tr>
<td>M2x</td>
<td>1.96</td>
<td>38</td>
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<tr>
<td>M4x</td>
<td>1.96</td>
<td>39</td>
</tr>
<tr>
<td>LM2x</td>
<td>1.84</td>
<td>38</td>
</tr>
<tr>
<td>M2-</td>
<td>1.98</td>
<td>38</td>
</tr>
<tr>
<td>M4-</td>
<td>1.98</td>
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<tr>
<td>LM4-</td>
<td>1.87</td>
<td>39</td>
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</table>
Typical values of the handle power and its components

Senior women on average over 2000m

<table>
<thead>
<tr>
<th>Data</th>
<th>bh</th>
<th>SR</th>
<th>P_handle</th>
<th>P_handle</th>
<th>W_handle</th>
<th>F_handle</th>
<th>v_handle</th>
<th>t_drive</th>
<th>s_handle</th>
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<tr>
<td>unit</td>
<td>m</td>
<td>1/min</td>
<td>W</td>
<td>W</td>
<td>J</td>
<td>N</td>
<td>m/s</td>
<td>s</td>
<td>m</td>
</tr>
<tr>
<td>W1x</td>
<td>1.80</td>
<td>35</td>
<td>480-570</td>
<td>550-780</td>
<td>430-580</td>
<td>290-390</td>
<td>1.90-2.00</td>
<td>0.68-0.71</td>
<td>1.48</td>
</tr>
<tr>
<td>W2x</td>
<td>1.80</td>
<td>37</td>
<td>255-350</td>
<td>540-770</td>
<td>415-560</td>
<td>280-380</td>
<td>1.92-2.02</td>
<td>0.66-0.69</td>
<td>1.48</td>
</tr>
<tr>
<td>W4x</td>
<td>1.80</td>
<td>38</td>
<td>260-360</td>
<td>545-780</td>
<td>415-560</td>
<td>280-380</td>
<td>1.95-2.05</td>
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<td>1.48</td>
</tr>
<tr>
<td>LW2x</td>
<td>1.68</td>
<td>36</td>
<td>205-265</td>
<td>460-625</td>
<td>340-440</td>
<td>240-310</td>
<td>1.92-2.02</td>
<td>0.62-0.65</td>
<td>1.42</td>
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<tr>
<td>W2-</td>
<td>1.82</td>
<td>36</td>
<td>250-320</td>
<td>570-760</td>
<td>420-530</td>
<td>300-380</td>
<td>1.90-2.00</td>
<td>0.66-0.69</td>
<td>1.40</td>
</tr>
<tr>
<td>W8+</td>
<td>1.82</td>
<td>38</td>
<td>260-330</td>
<td>580-780</td>
<td>410-520</td>
<td>290-370</td>
<td>2.00-2.1</td>
<td>0.62-0.65</td>
<td>1.40</td>
</tr>
</tbody>
</table>
## Evaluation of the handle power

<table>
<thead>
<tr>
<th>Total evaluation</th>
<th>Handle power in the stroke cycle (e.g. over 2000m)</th>
<th>$P_{\text{handle}}$ cycle</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>direct effect</strong></td>
<td>• stroke rate &lt;br&gt; • handle power in the drive phase &lt;br&gt; • handle work in the drive phase &lt;br&gt; • handle force in the drive phase &lt;br&gt; • handle velocity in the drive phase &lt;br&gt; • effective stroke length &lt;br&gt; • drive time</td>
<td>$SR$ &lt;br&gt; $W_{\text{handle}}$ &lt;br&gt; $F_{\text{handle}}$ &lt;br&gt; $s_{\text{handle}}$ &lt;br&gt; $v_{\text{handle}}$ &lt;br&gt; $t_{\text{drive}}$</td>
</tr>
<tr>
<td><strong>indirect effect and details</strong></td>
<td>• handle force in &lt;br&gt; - start of drive &lt;br&gt; - middle of drive &lt;br&gt; - finish of drive &lt;br&gt; • handle velocity in &lt;br&gt; - start of drive &lt;br&gt; - middle of drive &lt;br&gt; - finish of drive &lt;br&gt; • stroke length &lt;br&gt; - minimal angle &lt;br&gt; - maximal angle &lt;br&gt; • seat velocity in the drive phase &lt;br&gt; - start of drive &lt;br&gt; - middle of drive</td>
<td>$F_{\text{handle}}$ &lt;br&gt; $v_{\text{handle}}$ &lt;br&gt; $s_{1}$ &lt;br&gt; $\phi_{\text{min}}$ &lt;br&gt; $\phi_{\text{max}}$ &lt;br&gt; $v_{\text{seat}}$</td>
</tr>
</tbody>
</table>
Characteristic stretcher force-time curves

ideal curves   curves with error illustrations

- slowing down the trunk swing via the stretcher, 20)
- trunk is not recovered speedily after the hands away (pause) (21)
- starting the sliding too harshly (22)
- change on the stretcher from pulling to pressure force (23)
- strong braking of the forward sliding movement (24)
Characteristic values ($F_{\text{stretcher}}$)
recovery

Stretcher force [m/s]

- $F_{\text{min}}$
- $\varphi_{F_{\text{st}}=0N}$

Drive
Recovery

Angle [°]
### Evaluation of the recovery phase through stretcher force and seat velocity values

#### Characteristics of the recovery phase

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Formula(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>direct effect</strong></td>
<td></td>
</tr>
<tr>
<td>minimum of the stretcher force in the</td>
<td>( V_{\text{stretcher min}} )</td>
</tr>
<tr>
<td>recovery [N]</td>
<td></td>
</tr>
<tr>
<td>oar angle to the point of zero stretcher force (Chance the stretcher force of pull to pressure force in the recovery) [°]</td>
<td>( \varphi_{F_{\text{st}}=0N} )</td>
</tr>
<tr>
<td>average seat velocity in the recovery</td>
<td>( v_{\text{seat}} )</td>
</tr>
<tr>
<td>[m/s]</td>
<td></td>
</tr>
<tr>
<td><strong>indirect effect and details</strong></td>
<td></td>
</tr>
<tr>
<td>seat displacement [m]</td>
<td>( S_{\text{seat}} )</td>
</tr>
<tr>
<td>minimal seat velocity in the recovery</td>
<td>( v_{\text{seat min}} )</td>
</tr>
<tr>
<td>(maximum of the seat velocity in the forward direction) [m/s]</td>
<td></td>
</tr>
</tbody>
</table>
Characteristic boat force-time curves

- discontinuities front reversal (25)
- late or interrupted development of boat-force in the start of drive (26)
- negative boat force at the finish (27)
- negative boat force in the back reversal (28)
- starting the sliding too harshly (22)
- change on the stretcher from pulling to pressure force (23)
- strong braking of the forward sliding movement (24)
Characteristic boat speed-time curves

- boat speed starts to increase (29),
- increase is continuous or with interruptions (30)
- In the recovery phase the effects of
  - extraction (31)
  - forward sliding (32)
  - slowing down (33)
  - front reversal and catch (34)
Characteristic values ($v^{\text{boat}}$)

<table>
<thead>
<tr>
<th>Test</th>
<th>Strokes</th>
<th>SR  [1/min]</th>
<th>$s_b$ [m]</th>
<th>$v_b$ [m/s]</th>
<th>$v_{b\text{min}}$ [m/s]</th>
<th>$v_{b\text{max}}$ [m/s]</th>
<th>$\Delta v_b$ [m/s]</th>
<th>$\Delta v_b$ [%]</th>
<th>$v_{b\phi\text{min}}$ [m/s]</th>
<th>$v_{b\phi\text{max}}$ [m/s]</th>
</tr>
</thead>
<tbody>
<tr>
<td>0047</td>
<td>209</td>
<td>36.9</td>
<td>9.24</td>
<td>5.66</td>
<td>4.29</td>
<td>5.62</td>
<td>2.68</td>
<td>47.6</td>
<td>5.62</td>
<td>5.77</td>
</tr>
</tbody>
</table>
Characteristic values ($v^{\text{boat}}$)

Boat velocity depends on the stroke rate (SR)

<table>
<thead>
<tr>
<th>Test</th>
<th>Strokes</th>
<th>SR [1/min]</th>
<th>$s_b$ [m]</th>
<th>$v_b$ [m/s]</th>
<th>$v_{b\text{min}}$ [m/s]</th>
<th>$v_{b\text{max}}$ [m/s]</th>
<th>$\Delta v_b$ [m/s]</th>
<th>$\Delta v_b$ [%]</th>
<th>$v_{b\phi\text{min}}$ [m/s]</th>
<th>$v_{b\phi\text{max}}$ [m/s]</th>
</tr>
</thead>
<tbody>
<tr>
<td>0047</td>
<td>10</td>
<td>20.0</td>
<td>12.65</td>
<td>4.21</td>
<td>3.18</td>
<td>4.32</td>
<td>1.44</td>
<td>34.2</td>
<td>3.92</td>
<td>4.49</td>
</tr>
<tr>
<td>0047</td>
<td>10</td>
<td>24.5</td>
<td>11.57</td>
<td>4.72</td>
<td>3.60</td>
<td>4.78</td>
<td>1.73</td>
<td>36.8</td>
<td>4.50</td>
<td>4.97</td>
</tr>
<tr>
<td>0047</td>
<td>10</td>
<td>29.2</td>
<td>10.51</td>
<td>5.12</td>
<td>3.95</td>
<td>5.14</td>
<td>2.04</td>
<td>39.9</td>
<td>4.88</td>
<td>5.33</td>
</tr>
<tr>
<td>0047</td>
<td>209</td>
<td>36.9</td>
<td>9.24</td>
<td>5.66</td>
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<td>5.62</td>
<td>2.68</td>
<td>47.6</td>
<td>5.62</td>
<td>5.77</td>
</tr>
</tbody>
</table>
# Evaluation of boat velocity fluctuation

<table>
<thead>
<tr>
<th>Total evaluation</th>
<th>( V_{\text{boat}} )</th>
<th>( \Delta V_{\text{boat}} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>• average boat velocity [m/s]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• innercycle boat velocity fluctuation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>– absolute [m/s]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>– as a percentage of the average boat</td>
<td></td>
<td></td>
</tr>
<tr>
<td>velocity [%]</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>direct effect</th>
<th>( SR )</th>
<th>( V_{\text{boat min}} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>• stroke rate [1/min]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• minimum boat velocity [m/s]</td>
<td>( V )</td>
<td></td>
</tr>
<tr>
<td>• maximum boat velocity [m/s]</td>
<td>( V_{\text{boat max}} )</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>indirect effect and details</th>
<th>( V_{\text{boat } \phi_{\text{max}}} )</th>
<th>( V_{\text{boat } \phi_{\text{min}}} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>• boat velocity during minimum oar angle [m/s]</td>
<td>( V_{\text{boat } \phi_{\text{max}}} )</td>
<td>( V_{\text{boat } \phi_{\text{min}}} )</td>
</tr>
<tr>
<td>• boat velocity during maximum oar angle [m/s]</td>
<td>( V_{\text{boat } \phi_{\text{max}}} )</td>
<td>( V_{\text{boat } \phi_{\text{min}}} )</td>
</tr>
</tbody>
</table>
The diagnosis of rowing technique faults

- Identification of a divergence by comparison with an ideal pattern
- During which oar-angle sector does the deviation appear?
- Which peculiarities do the other characteristic curves in the corresponding rowing phase exist?
- What effect is this having on the main aim (boat speed)?
- Which faulty movement is hiding itself behind the divergence?
- Formulation of precise movement instructions for oarsmen and crew.
Biomechanical feedback in the racing boat
Intention: Removal of faults in rowing technique
e.g. the dynamic time structure

Current state of technique → feedback-training → learning progress
Reasons for biomechanical feedback

• Some mistakes in rowing technique are hard to eliminate (force structure).
• Kinaesthetic information is unconsciously.
• Force patterns are difficult to observe by the coach.
• Coach and athlete need more quantitative information with higher precision.
Trainer’s display

Athlete’s displays

Telemetry
Feedback display
Feedback display
Feedback training procedure

• Before feedback training: biomechanical analysis of technique to identify the objectives of feedback training
• In feedback training: the athletes are asked to vary the movement in order to change a technical feature. The athlete monitors and regulates the movement with the help of objective feedback
• If the athlete succeeds, the objective feedback information is withdrawn step by step. The athlete learns to produce the altered movement pattern without external feedback
• Retention tests: the altered movement is stable under competitive conditions and without objective feedback
Comparison between Pre-test und 1. TU, 4x, No. 4, stroke side, stroke rate 20 [1/min]

<table>
<thead>
<tr>
<th>Angle [°]</th>
<th>Pre-test</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>0</td>
</tr>
<tr>
<td>40</td>
<td>200</td>
</tr>
<tr>
<td>60</td>
<td>400</td>
</tr>
<tr>
<td>80</td>
<td>600</td>
</tr>
<tr>
<td>100</td>
<td>800</td>
</tr>
<tr>
<td>120</td>
<td>1000</td>
</tr>
<tr>
<td>140</td>
<td>1200</td>
</tr>
</tbody>
</table>

Force [N]
Comparison between Pre-test und 1. TU, 4x, No. 4, stroke side, strokerate 20

-200 0 200 400 600 800
20 40 60 80 100 120 140

Force [N]  Angle [°]

---

- Pre-test
- 1. TU with display
- 1. TU without Display

---
Comparison between pre-test and third training unit (TU), 4x, SR 20

Seat 4, stroke side

<table>
<thead>
<tr>
<th>Force [N]</th>
<th>Angle [°]</th>
<th>Acceleration [m/s²]</th>
</tr>
</thead>
<tbody>
<tr>
<td>pre-test</td>
<td>third TU display</td>
<td>third TU no display</td>
</tr>
<tr>
<td>-200</td>
<td>20</td>
<td>0</td>
</tr>
<tr>
<td>0</td>
<td>40</td>
<td>2</td>
</tr>
<tr>
<td>200</td>
<td>60</td>
<td>4</td>
</tr>
<tr>
<td>400</td>
<td>80</td>
<td>2</td>
</tr>
<tr>
<td>600</td>
<td>100</td>
<td>0</td>
</tr>
<tr>
<td>800</td>
<td>120</td>
<td>-2</td>
</tr>
<tr>
<td>62</td>
<td>140</td>
<td>-4</td>
</tr>
</tbody>
</table>

Graph showing force, angle, and acceleration data for Seat 4, stroke side.
Gate-force-angle curve for an athlete before, during as well as after feedback

before feedback | during and after feedback

SR = stroke rate
d = with display
nd = no display
Comparison of the first test and deviation of intervention

Force [N] 

feedback training with display

training without Display

female, 4x, No. 1

first test

bow side  stroke side

t [s]

6 9

64
Approach using stroke length in big boats, N=4

First test
SR=30 1/min

Feedback training
SR=30 1/min

<table>
<thead>
<tr>
<th>Angle [°]</th>
<th>Force [N]</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>-200</td>
</tr>
<tr>
<td>40</td>
<td>0</td>
</tr>
<tr>
<td>60</td>
<td>200</td>
</tr>
<tr>
<td>80</td>
<td>400</td>
</tr>
<tr>
<td>100</td>
<td>600</td>
</tr>
<tr>
<td>120</td>
<td>800</td>
</tr>
<tr>
<td>140</td>
<td>1000</td>
</tr>
</tbody>
</table>

No. 1
No. 2
No. 3
No. 4
Feedback training

- Information about various aspects of technique in the propulsive and recovery phases, like
  - Spatial attributes of the stroke length
  - Space-time attributes of the oar and body movement
  - Dynamic-time attributes of the force applied to the handle and stretcher
  - Attributes of the boat movement (speed and acceleration)
Reinforce strokes with positive characteristics

Positive and negative force curve characteristics for individual strokes

![Graph showing force (F) vs. angle (°) for positive and negative characteristics. The graph includes a red and a blue line, representing negative and positive forces, respectively. The x-axis represents angle in degrees (°), ranging from 20 to 120, and the y-axis represents force (F) in Newtons (N), ranging from -200 to 1200.](image-url)
Feedback training

- **short intervention**
  - (2-4 TU)
    - fine adjustment
      - in crew boat
    - technique-practice training
      - (reinforcement of emerging movement pattern)

- **long intervention**
  - (>10 TU)
    - error removal
      - in crew boat
    - technique-acquisition training
      - (unlearn and learn anew)
For more information

Altenburg D, Mattes K & Steinacker J

Manual for Rowing Training
Technique, High Performance and Planning

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Diagnostic of rowing performance and technique to optimise the rowing technique

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