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Practical Applications of Rowing Biomechanics

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Basic chart of Rowing Biomechanics

What we are going to talk about?
- Tools for biomechanical measurements in rowing;
- Biomechanical “Gold Standards”;
- Force curve and dynamics of the system;
- Segment’s velocities and rowing styles;
- Phases of the stroke cycle;
- Vertical angle and blade efficiency;
- Biomechanics for rigging.

What Biomechanical Tools we use?
- BioRowTel v4.5 telemetry system was created by rowing scientist for research purposes. It is accurate, flexible, scalable, based on “screening” concept, quick to setup, light;
- Scalable design: one “Master” unit + up to 8 “Slaves”;
- Master unit contains: GPS and impeller input for boat speed;
- 3D accelerometer, 3D gyro;
- Wind speed & direction input;
- Sampling frequency 25-100 Hz;
- Resolution 14 bit;
- Works >8 hours;
- Weight 300g.

Our history force measurements in rowing

Movie “Royal Regatta” was made in USSR in 1968. Producer: Jury Chalkine. Consultants: Samsonov (Head Coach of the National Team), Amring, Kobanov.
How can we deliver information to a rower in real time?

- Visual Feedback System VFS can be used with any standard video camera. The transmitter is attached to the video camera. VFS system worn by the athlete and the integral headphones allow the coach’s comments to be heard.
- VFS can be used for immediate feedback on various elements of technique: oar blade work, leg work, arm work, synchronization of the crew, etc.

How can we present the Force Curve?

- Force vs. stroke rate is another option;
- Force vs. Oar Angle allows easy comparison at various stroke rates and useful for defining position of specific points (peaks, gaps).

How to process data with BioRowTel system

- Averaging algorithm implemented in the software allows:
  - Unambiguous analysis of massive rowing data,
  - Easy comparison of various samples: rowers in the boat, various stroke rates, previous and current data;
  - Accuracy <1%.

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What are Rowing Biomechanics “Gold Standards”?

<table>
<thead>
<tr>
<th>Event</th>
<th>GSR Time</th>
<th>P (W)</th>
<th>Erg Score (m/s)</th>
<th>Angle (deg)</th>
<th>Fav (W)</th>
<th>Force (N)</th>
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Category: W (kg) | P (W) | Erg Score (m/s) | Angle (deg) | Fav (W) | Force (N) |
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<td>100</td>
<td>150</td>
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<td>150</td>
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</table>

Fav = 0.83 * WPS / L

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How can we present the Force Curve?

- Force vs. stroke rate is another option;
- Force vs. Oar Angle allows easy comparison at various stroke rates and useful for defining position of specific points (peaks, gaps).
Why the front loaded-drive is more effective?

Front-loaded drive (F1):
- Gives 47% higher average velocity and distance travelled during the drive;
- Creates much more even distribution of the power;
- Provide better utilization of the most powerful muscle groups;
- Hydro-lift force on the blade can be used better.

How the front-loaded drive looks like?
- It is important to increase force quickly up to 70% of maximum;
- “Trampolining” effect?

How can we analyse the Force Curve?
- Catch gradient defines how quickly the force increases;
- Position of the Peak Force defines emphasis of force application;
- Finish gradient defines how long the force maintained.

How the Target Force Curve looks like?
- Solid, front-loaded, full, no ‘humps’ or glitches;
- Catch gradient 10% of the Total Angle (11 deg in sculling, 9 deg in rowing);
- Position of the Peak Force 33% of Total Angle (down to 30% in 8+ and 4x, up to 38% in 1x);
- Finish gradient 32% (up to 36% in big boats, down to 26% in small boats).

How we analyze rower’s blade work?
- Two-dimensional (2D) sensor measures oar angles horizontal and vertical planes, which allows to define a path of the blade relative to water.
- Criterion -3 deg was chosen to indicate full immersion of the blade into the water.

What we need to know about blade efficiency?
- Hydro-lift force works at sharp angles of attack and contributes 56% of the blade propulsive force;
- Drag force works at the middle of the drive and contributes 44% of the blade propulsive force.

How can we increase the blade propulsive efficiency?
- Use bigger blade area;
- Use heavier gearing;
- Utilise hydro-lift effect - apply more force at sharp oar angles at catch;
- Place the blade at the optimal depth under the water (4-6 deg).
How we measure velocities of body segments?

- Cable position transducers are attached to the seat and top of the trunk (at the level L7-Th1 vertebra or sternum-clavicle joints);
- Arms velocity is calculated as a difference between handle velocity (derived from oar angle and inboard) and trunk velocity.

Why “humps” of the Force Curve happen?

- Usually, the hump happens at about ¼ of the drive after the catch;
- The most common reason is early “opening” the trunk at catch, followed by a “hump” of trunk speed;
- The handle is driven upwards, the blade goes down and creates very heavy resistance, which do not allow rower to “push through”.

How effective sequence of segments looks like?

- Legs start the drive with velocity equal to the handle velocity;
- Trunk starts at the knee angle about 90 deg (handle position on top of the stretcher);
- Arms and shoulders starts slowly soon after the trunk and accelerates at the finish.

How segments sequence defines Rowing Style?

A popular classification of Rowing Styles by Peter Klavora (1979) and appended (RBN 2006/03) classify techniques on the basis of legs-trunk coordination and emphasis during the drive.

The 1st reason to start with legs: muscles-antagonists

- Quadriceps (Rectus femoris & Sartorius) are connected to the shins and (partly) to the pelvis;
- Hamstrings (Biceps femoris long head & Semi-tendinosus) are connected to the shins and to the pelvis.

The 2nd reason to start with legs: “Catch through the stretcher”

- “Catch through the stretcher” gives 46% higher velocity of the blade at the same handle velocity;
- “Catch through the stretcher” is preferable because of using of more powerful muscle groups.
How fast legs reflect in the boat acceleration?

- Magnitudes of both negative peak and the first peak of the boat acceleration are highly dependent on the stroke rate.
- No significant difference was found between sculling and sweep rowing.
- The pattern is quite similar in all boat sizes.
- The best rowing crews have the highest magnitude of the negative peak of the boat acceleration at catch and the highest first peak.

When the trunk should start?

- At the catch the force is applied through the toes, which decrease Lh and increase leverage around knee joint.
- After 1/3 of the drive the point is shifted to the heels, which increase Lh (more lift of the rower’s weight) and decrease leverage around hip joint.
- Ability to shift from the point of force application toes to heels and emphasis from quads to hamstrings is very important component of rower’s skill.

How to perform effective Finish?

1. “Finish through the handle” creates additional force of the blade, which propels the boat-rower system.
2. “Finish through the handle” does not push the boat down;
3. “Finish through the handle” uses more effective leverage of the oar;
4. “Finish through the handle” allows earlier relaxation of the legs muscles.
5. “Finish through the handle” must be performed during the shortest possible time and travel of the handle.

Losses due to early squaring the blades

- This double is losing about 10 seconds due to early squaring (at no wind conditions)
- This double will lose about 30 seconds at head wind 5m/s

Sub - phases of the stroke cycle

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<tbody>
<tr>
<td>Recovery:</td>
<td>R1. Arms and Trunk Return;</td>
<td>R2. Stretcher pull;</td>
<td>R3. Stretcher push;</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

Recovery R2
- Stretcher Pull
- Legs is beginning the movement,
- Trunk is finishing preparation
Recovery R3  
- Stretcher Push  
  - Max. speed of the legs,  
  - Trunk is ready to drive.

Drive D1  
- Blade immersion;  
- D2 Initial Rower’s Acceleration  
  - Catch: the oar change the direction of the movement by means of legs kick through the stretcher.

Drive D3  
- Initial Boat Acceleration  
  - Extending knees using quads,  
  - Pushing the stretcher through toes.

Drive D4  
- The main rower’s acceleration  
  - Pushing the knee down using hamstrings and gluts  
  - Start using the trunk.

Drive D5  
- The main Boat acceleration  
  - Legs are finishing,  
  - Maximal trunk speed,  
  - Start using arms and shoulders.

Drive D6,  
- Blade removal  
  - Return of the trunk by means os fast arms drive.
Strong posture: effective back curve

Straight lumbar area can help to transfer the force better from hips to shoulders and prevent injuries;

more curvature in the thoracic area can be more economical because it uses more elastic properties of the muscles rather than its strength.

Lateral pitch

Lateral pitch is useful to overcome the difference in comfortable height of the handle;

It helps to maintain a more constant force vector, because

It increases the blade pitch at catch and decreases it at finish.

Analysis of Lumbar and Thoracic angles

The best scullers have significantly straighter lumbar angles and more curved thoracic angle.

Good rowing drills

<table>
<thead>
<tr>
<th>Drill</th>
<th>Purpose</th>
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</thead>
<tbody>
<tr>
<td>1 Rowing with feet out</td>
<td>Emphasise the stretcher pressure and fast arms drive at finish of the drive</td>
</tr>
<tr>
<td>2 Late squaring of the blades</td>
<td>Preventing feathering in the water and developing good balance</td>
</tr>
<tr>
<td>3 Arms with shoulders</td>
<td>Active using of the shoulders, arms – shoulders coordination.</td>
</tr>
<tr>
<td>4 ¾ slide – fast trunk</td>
<td>Concentrate of fast horizontal trunk drive</td>
</tr>
<tr>
<td>5 Catch – legs only</td>
<td>Concentrate on the fast blade placement into the water and quick kick to the stretcher</td>
</tr>
</tbody>
</table>
Catch – legs only drill

Concentrate on the fast blade placement into the water and quick kick to the stretcher.

Fast trunk drill

Concentrate on the fast horizontal trunk drive

What we can measure in rigging?

- Oar dimensions define gearing, which determines force/velocity ratio of rower’s muscles contraction;
- Stretcher position is related to ratio of catch/finish angles;
- Gate height and blade pitch defines vertical oar angles;
- Stretcher angle and height defines lift force and kinetics of the drive.

Gate height and pitch

- If pulling with straight arms at pitch 12 deg, then 20% of the total force is directed vertically ($\sin(\alpha)$) and propulsive force is decreased by 2.2% ($1-\cos(\alpha)$), which is very significant loss.
- In case of the most common pitch 4 deg, only 0.24% of the propulsive force is lost;
- Every 1 cm of decrease of the gate height makes the force vector 0.6 deg more vertical and vice versa.
- The height of the handle (and gate) is defined mainly by a comfort for a rower at finish;
- A lower gate height requires more pitch and more significant arms "grubbing" and vice versa.

What is correct definition of the Gearing?

- The standard definition of the gearing is the ratio of velocities (or displacements, travels) of output to input;
- In rowing, velocity of the output is defined by actual outboard, input – by actual inboard;
- The span/spread does NOT affect gearing;
- Blade efficiency or "slippage" DOES affect Gearing.

Is gearing constant during the drive?

- At sharp oar angles only part of blade velocity is parallel to the boat velocity;
- Effect of the oar angle is small until 45 deg;
- Gearing ratio became twice heavier at the oar angle 60 deg;
- Gearing ratio became three times heavier at the oar angle 70 deg;
- Gearing ratio became six times heavier at the oar angle 80 deg;
- The most common catch angles are between 55 deg (sweep) and 70 deg (sculling).
The span affects gearing indirectly

Effect of the span on the catch angle:
- Two centimetres of shorter spread gives only 0.5 deg of extra catch angle;
- If we change inboard accordingly to maintain overlap, this would give us 0.8 deg of extra catch angle for every 2cm of extra spread.

“Cost” of one degree of the oar angle at catch, when change the stretcher position

- One degree equals about 1.5cm of the arc length in sculling and 1.75cm in sweep rowing
- Change of the stretcher position affects more catch angle than finish angle

How can we help to optimize rigging?
Rigging Calculator [www.biorow.com/RigChart.aspx](http://www.biorow.com/RigChart.aspx)

Thank you for attention

- Dr. Valery Kleshnev
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- Rowing Biomechanics Newsletter
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