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2011 WORLD ROWING COACHES CONFERENCE
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Biomechanics for Effective Rowing Technique

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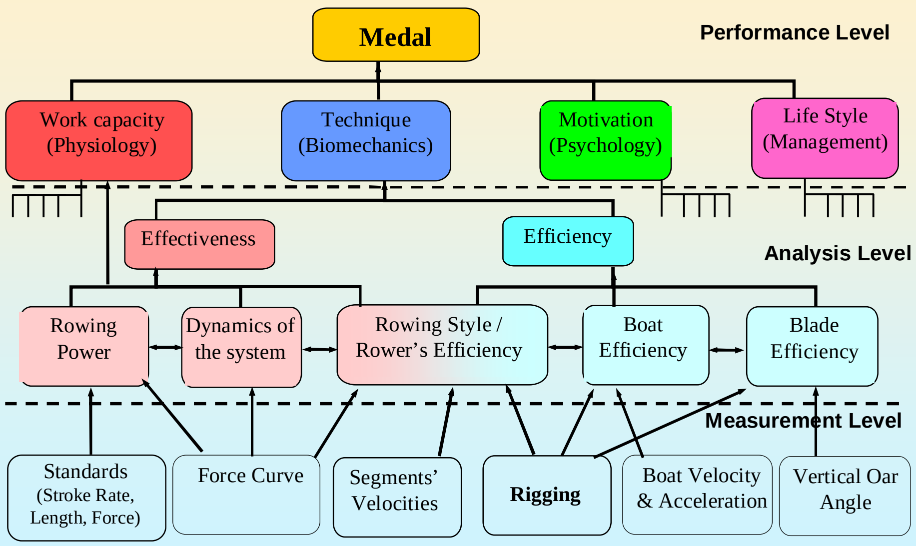
Basic chart of Rowing Biomechanics



From: Kleshnev V. 2011. Rowing Biomechanics.
In: Rowing Faster, the 2nd edition, ed. Nolte V. Human Kinetics

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What we are going to talk about?

- Biomechanical “Gold Standards”;
- Tools for biomechanical measurements in rowing;
- Force curve and dynamics of the system;
- Segment’s velocities and rowing styles;
- Vertical angle and blade efficiency;
- Biomechanics for rigging.

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What are Rowing Biomechanics “Gold Standards”?

Event	G.St. Time	P (W)	Inb. (m)	Rate (1/min)	Angle (deg)	Fav (N)	Fmax (N)
W1x	07:11.5	400	0.89	33.0	110	371	713
W2x	06:39.5	400	0.88	35.0	110	354	680
W4x	06:08.5	400	0.87	37.0	110	339	651
W2-	06:52.9	400	1.16	37.0	90	334	641
W8+	05:53.1	400	1.15	39.0	92	313	601
M1x	06:32.5	550	0.89	35.0	114	464	892
M2x	06:02.1	550	0.88	37.0	114	444	854
M4x	05:33.2	550	0.87	39.0	114	426	820
M2-	06:16.5	550	1.16	38.0	90	447	859
M4-	05:41.0	550	1.15	40.0	92	419	806
M8+	05:18.6	550	1.14	40.0	94	414	797
LW2x	06:47.0	330	0.88	35.0	106	303	583
LM2x	06:07.2	470	0.88	37.0	110	393	756
LM4-	05:46.2	470	1.15	40.0	90	366	704

Category	W (kg)	P (W)	Erg Score (m:s)
Open Women	85	400	6:23
Open Men	95	550	5:44
LW Women	60	330	6:48
LW Men	70	470	6:03

Pprop = DF * V^3

P = Pprop / Eblade

L = Inb. * A

WPS = P * (60 / Rate)

Fav = 0.83 * WPS / L

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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.

“Master” unit

“Slave” unit

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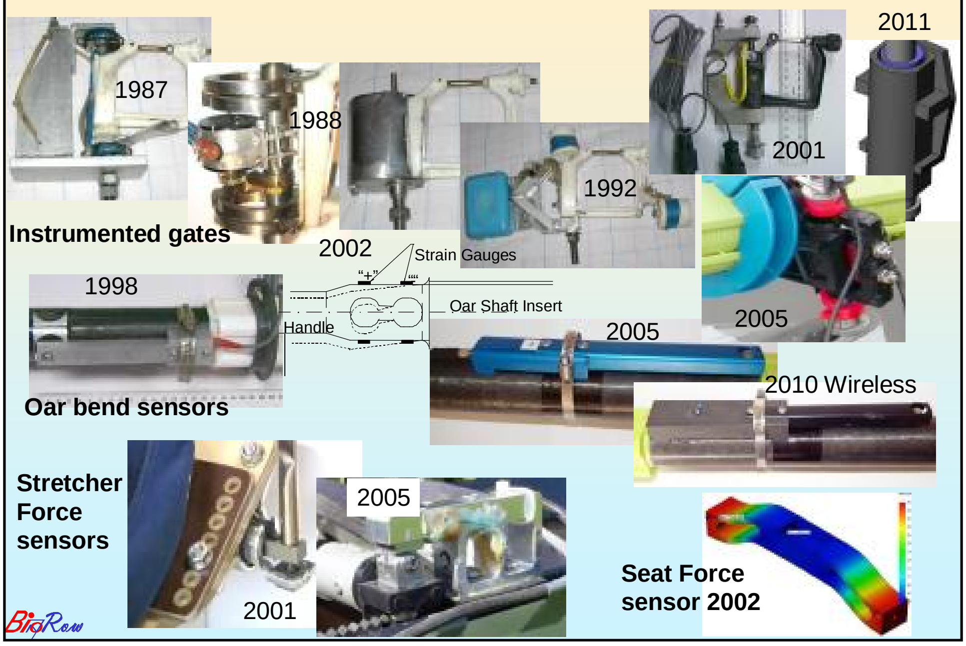
Our history force measurements in rowing



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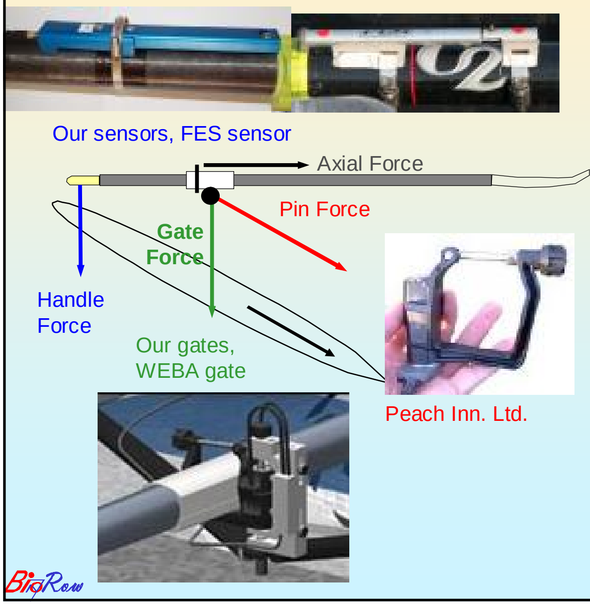
What is measured with force transducers?

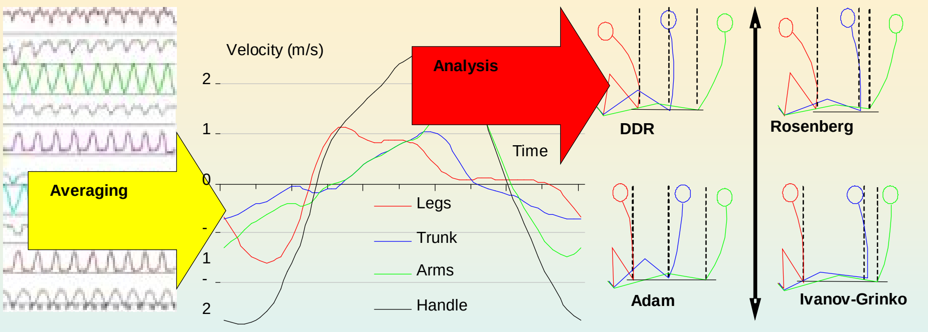


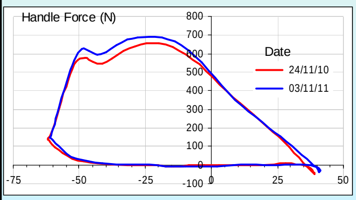
ü Handle Force gives the most accurate power measures, but require calibration of every oar.

ü Gate force require inboard for power calculation, which could vary during the drive ±5%;

ü Pin Force is affected by oar angle and axial force, so power could me measured with ±20% accuracy.

How we process data with BioRowTel system





Averaging algorithm implemented in the software allows:

ü Unambiguous analysis of massive rowing data,

ü Easy comparison of various samples: rowers in the boat, various stroke rates, previous and current data;

ü Accuracy <1%.

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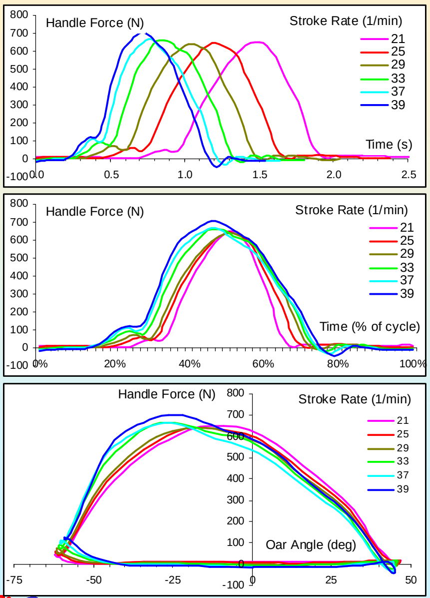
How can we present the Force Curve?



ü Force vs. time (s) is good for synchronisation with other variables, but difficult to compare at various stroke rates;

ü Force vs. time (% of stroke cycle) is another option;

ü Force vs. Oar Angle allows easy comparison at various stroke rates and useful for defining position of specific points (peaks, gaps).

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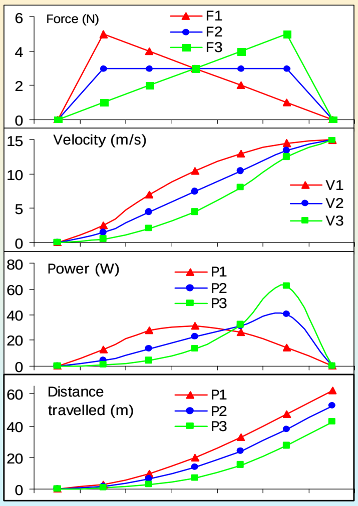
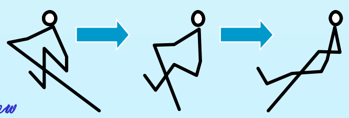
Why the front loaded-drive is more effective?





Front-loaded drive (F1):

ü Gives 47% higher average velocity and distance travelled during the drive;

ü Creates much more even distribution of the power;

ü Provide better utilization of the most powerful muscle groups

ü Hydro-lift force on the blade can be used better.

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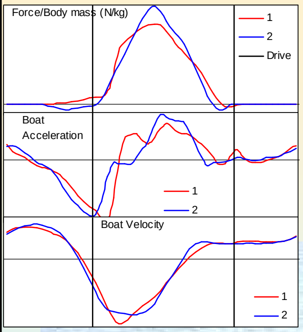
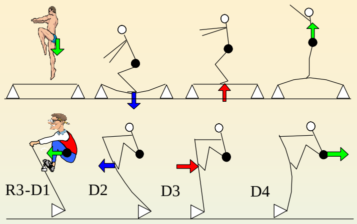
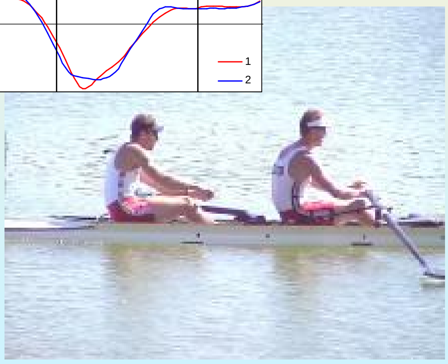
How the front-loaded drive looks like?



- It is important to increase force quickly up to 70% of maximum;
- "Trampolining" effect?

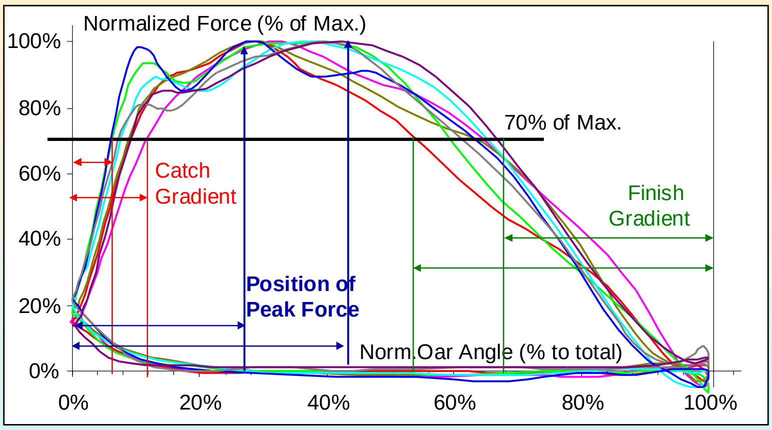




1. Front-loaded

1. Middle-loaded

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.

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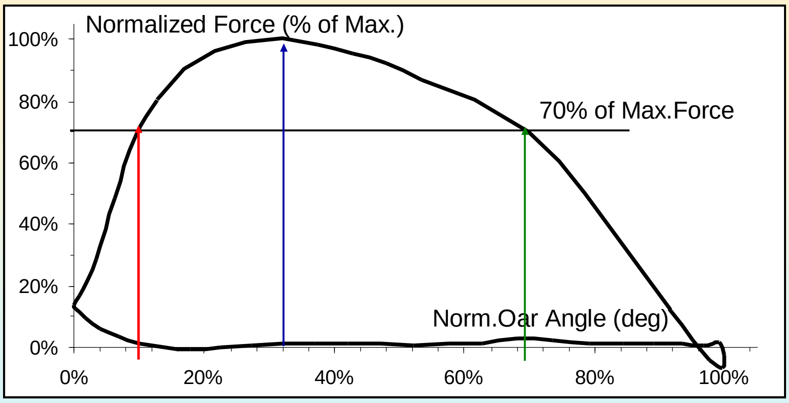
How the Target Force Curve looks like?



- 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).

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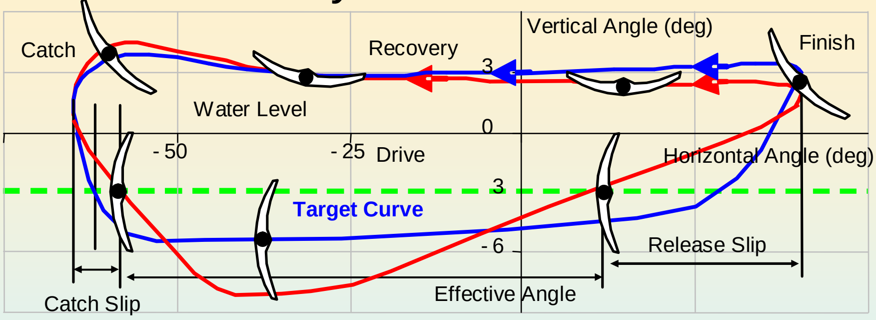
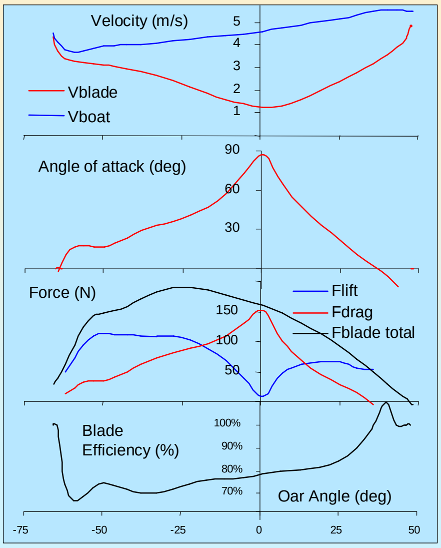
How we analyze rower’s blade work?



- 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.

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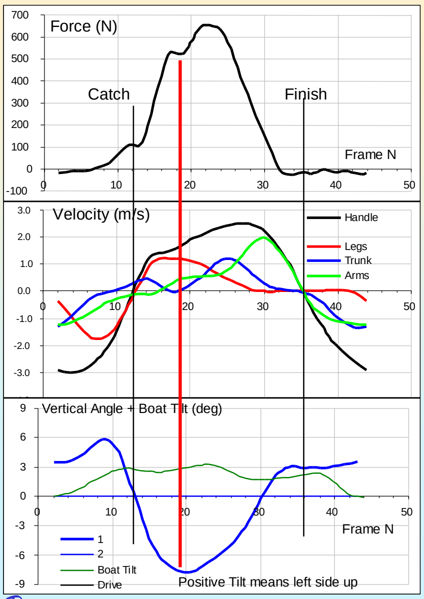
Why “humps” of the Force Curve happen?



ü Usually, the hump happens at about ¼ of the drive after the catch;

ü The most common reason is early “opening” the trunk at catch, followed by a “hump” of trunk speed;

ü The handle is driven upwards, the blade goes down and creates very heavy resistance, which do not allow rower to “push through”.

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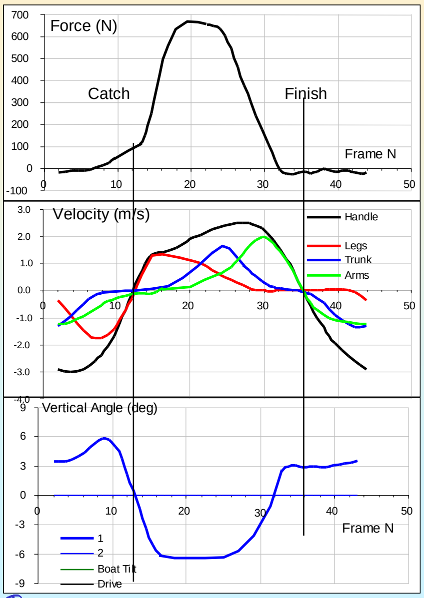
How effective sequence of segments looks like?



ü Legs start the drive with velocity equal to the handle velocity;

ü Trunk starts at the knee angle about 90 deg (handle position on top of the stretcher);

ü Arms and shoulders starts slowly soon after the trunk and accelerates at the finish.

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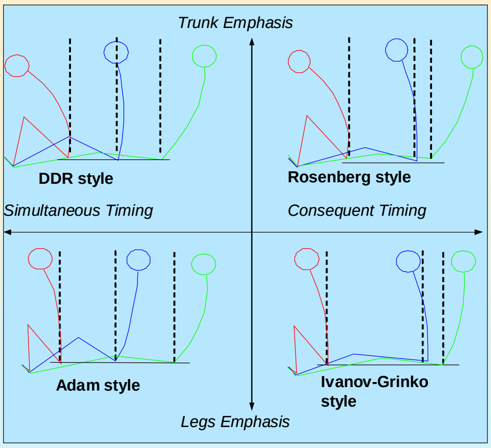
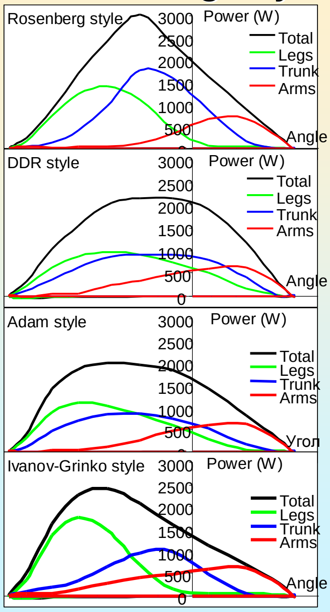
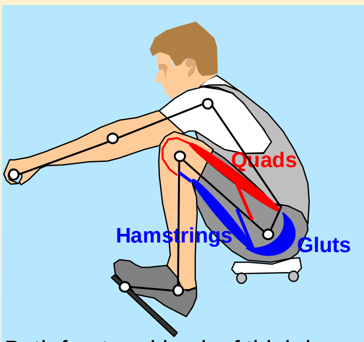
How segments sequence defines Rowing Style?





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.

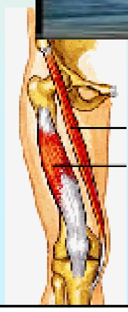
The 1st reason to start with legs: muscles-antagonists

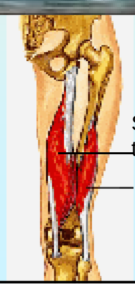


Both front and back of thigh has biarticulate muscles:

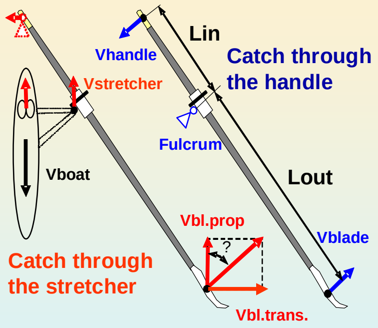
•Quads (*Rectus femoris & Sartorius*) are connected to the shins and (partly) to the pelvis;

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"



In case of "Catch through the handle":

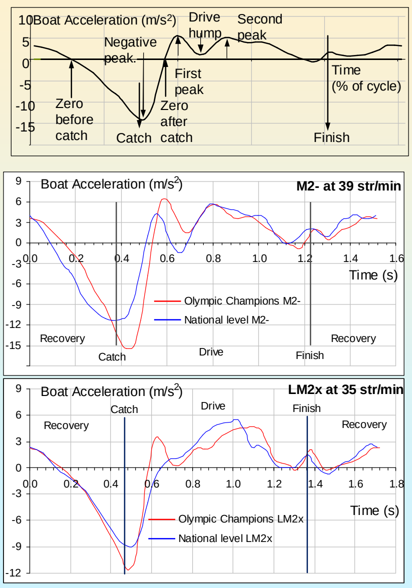
Vblade = Vhandle (Lout / Lin)

In case of "Catch through the stretcher":

Vblade = Vstr. ((Lout + Lin) / Lin)

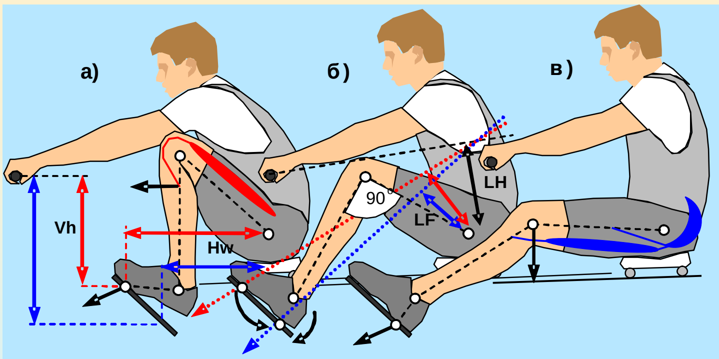
- «Catch through the stretcher» gives 46% higher velocity of the blade at the same handle velocity;
- «Catch through the stretcher» is preferable because of using of more powerful muscle groups.

How fast legs reflects 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.

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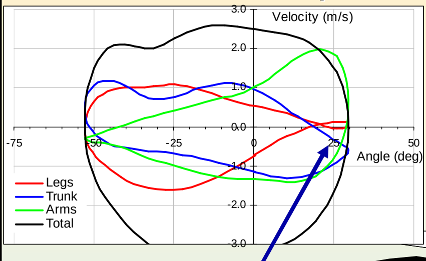
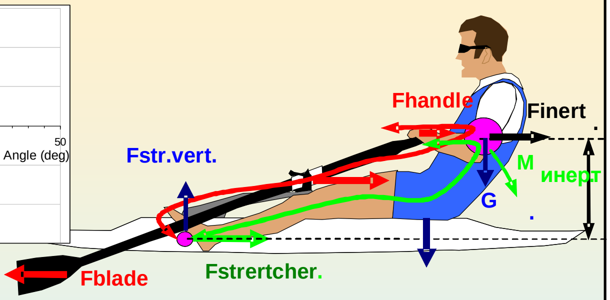
How to perform effective Finish?





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.

- "Finish through the handle" must be performed during the shortest possible time and travel of the handle.

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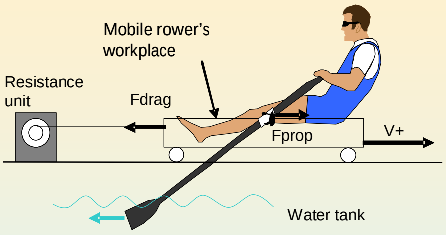
How can we deliver information to a rower in a real time?

üVisual 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.

üVFS can be used for immediate feedback on various elements of technique: oar blade work, leg work, arm work, synchronization of the crew, etc.

Would you like to feel on-water rowing during winter?



Mobile Rowing Tank (MRT) allows:

üPower transfer through the stretcher, which contribute nearly 40% of power production in on-water rowing.

üThere is a gearing effect similar to on-water rowing, where the stretcher force is 40% higher than the handle force.

üSimilar to on-water rowing, MRT requires more legs power, while stationary rowing requires more upper body power.

üThe stretcher acceleration makes vestibular sensations of the rower very similar to the sensations during on-water rowing.

üRowers can interact through the stretcher to develop an accurate synchronisation, similar to on-water rowing.

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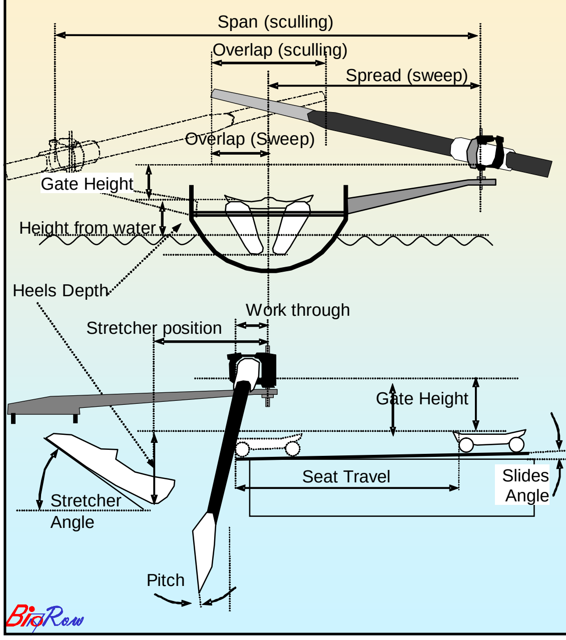
What we can measure in rigging?



Why rigging is important?

- 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.

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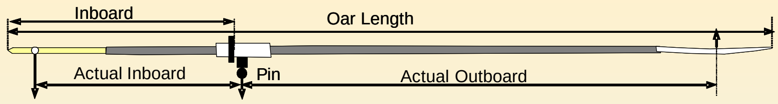
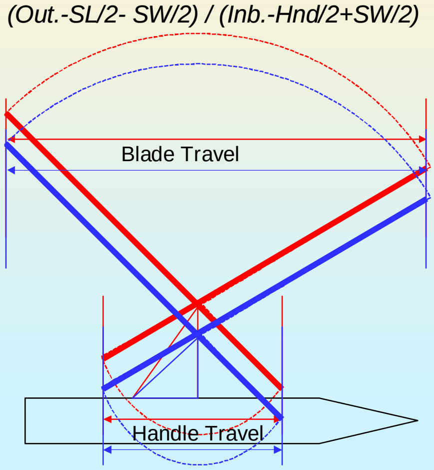
What is correct definition of the Gearing?



Gearing = Actual Outboard / Actual Inboard
= (Out.-SL/2- SW/2) / (Inb.-Hnd/2+SW/2)



- 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.

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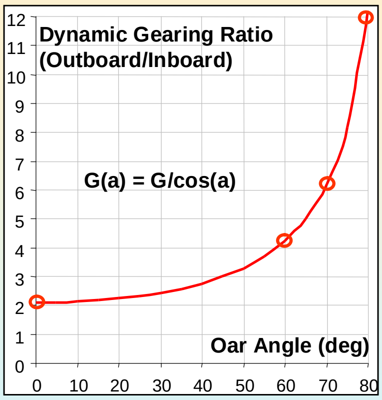
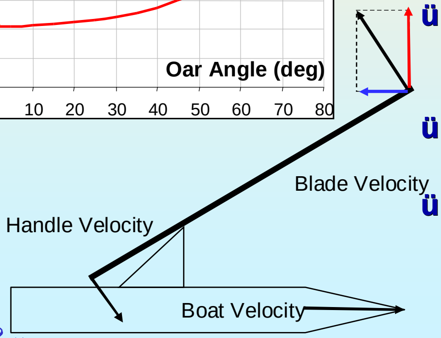
Is gearing constant during the drive?





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

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How can we help to optimize rigging?

Rigging Calculator www.biorow.com/RigChart.aspx

Thanks to Ian Wilson of Concept2 UK for the idea and
Dick & Peter Dreissigacker of Concept 2 for support.

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Thank you for attention

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