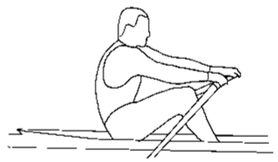
Universität Hamburg

DER FORSCHUNG | DER LEHRE | DER BILDUNG

UHH Bewegungs-& Trainingswissenschaft

Diagnostic of rowing performance and technique to optimise the rowing technique

Prof. Dr. Klaus Mattes



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Structure

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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

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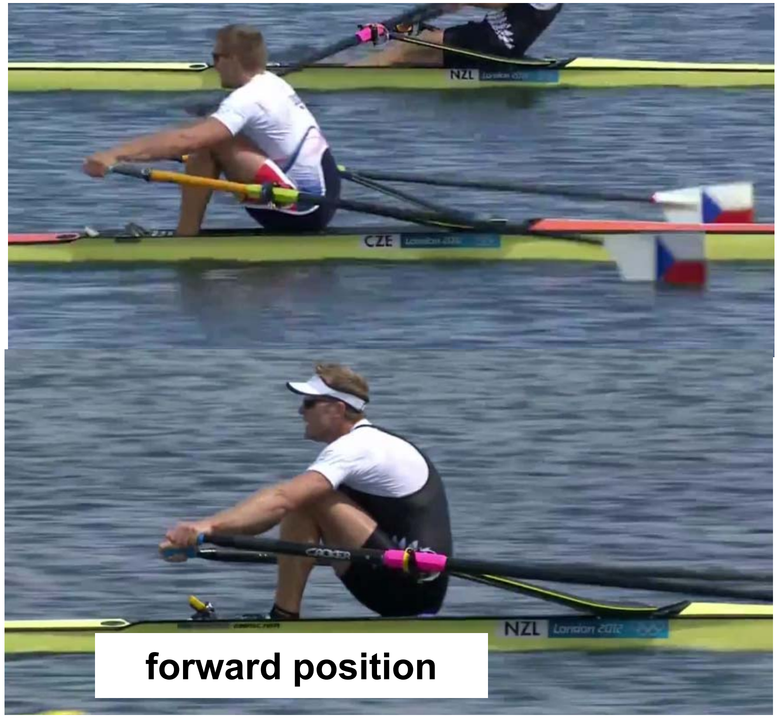
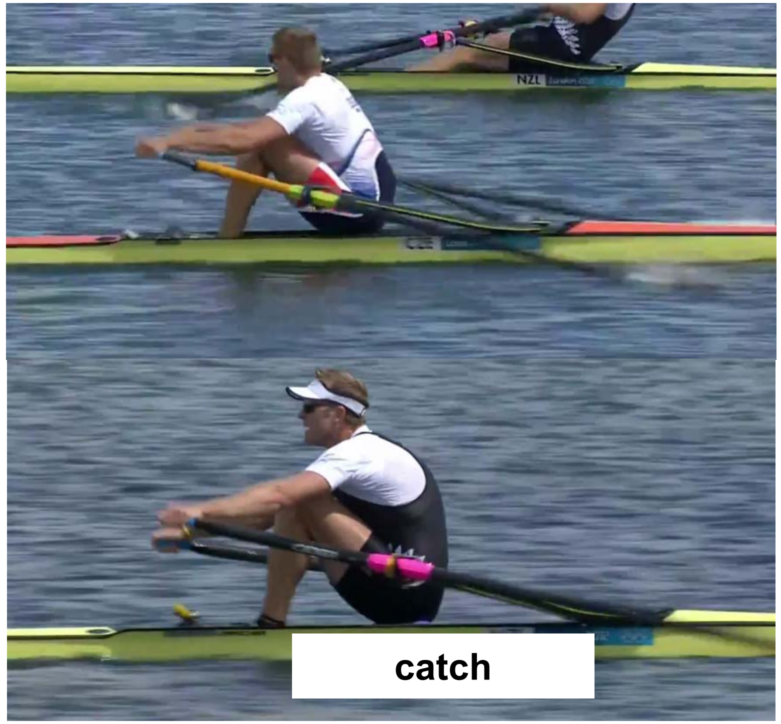
Drive CZE

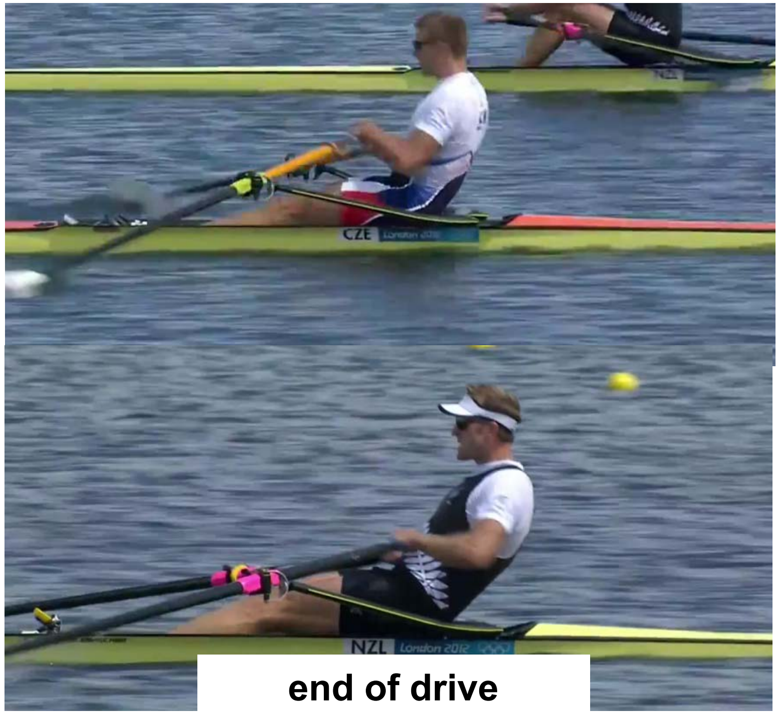
Drive NZL



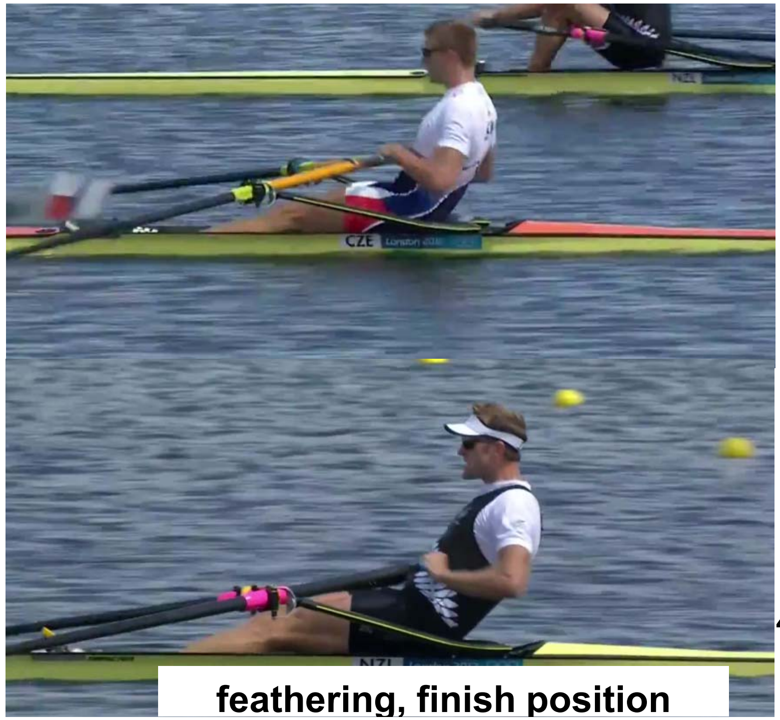
forward position



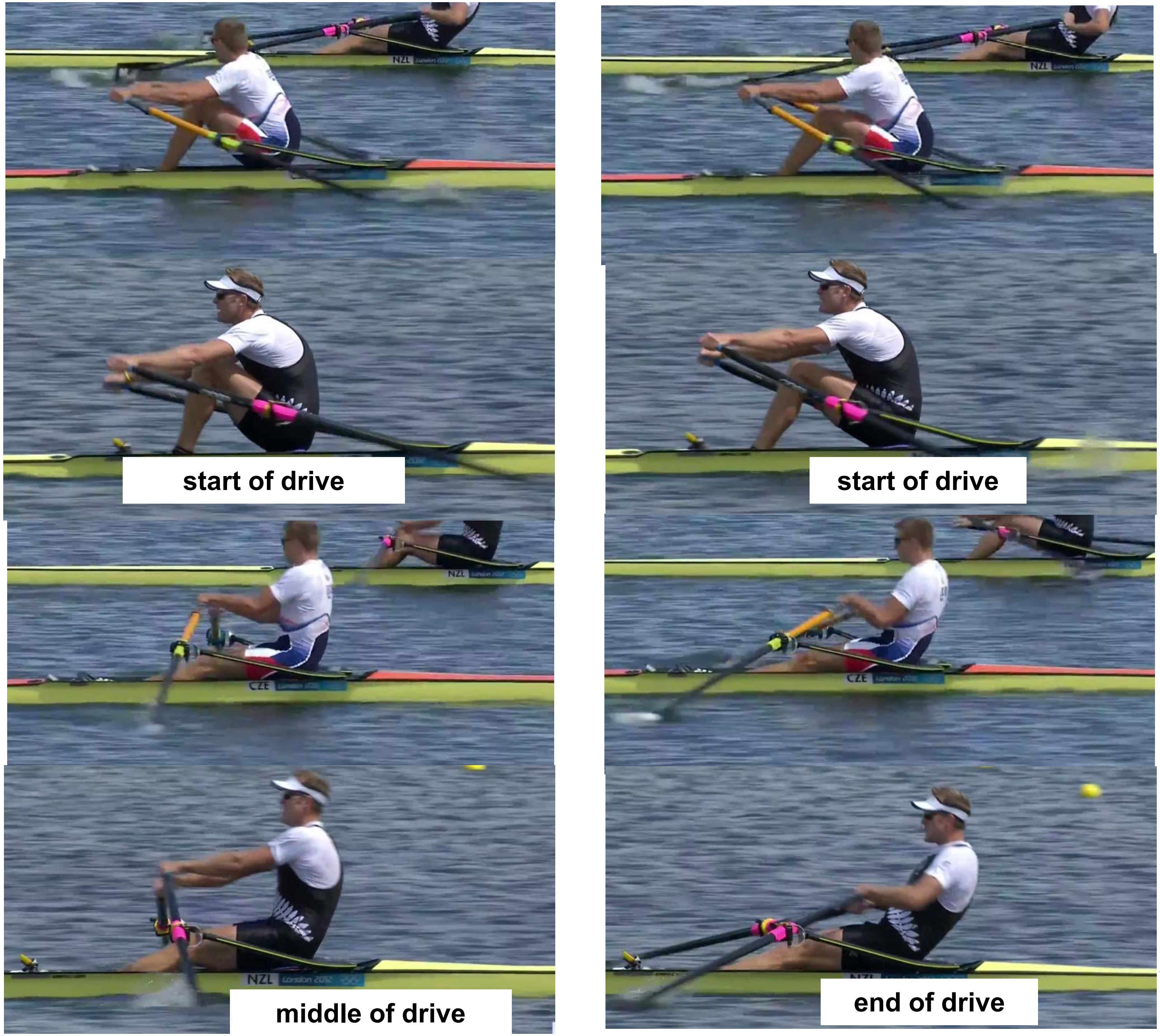
catch



end of drive



feathering, finish position


start of drive
start of drive
NZL
CZE
middle of drive
end of drive

The current mobile measuring and training system

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FES®

Final women‘s quadruple scull German Championships Berlin, june 2004

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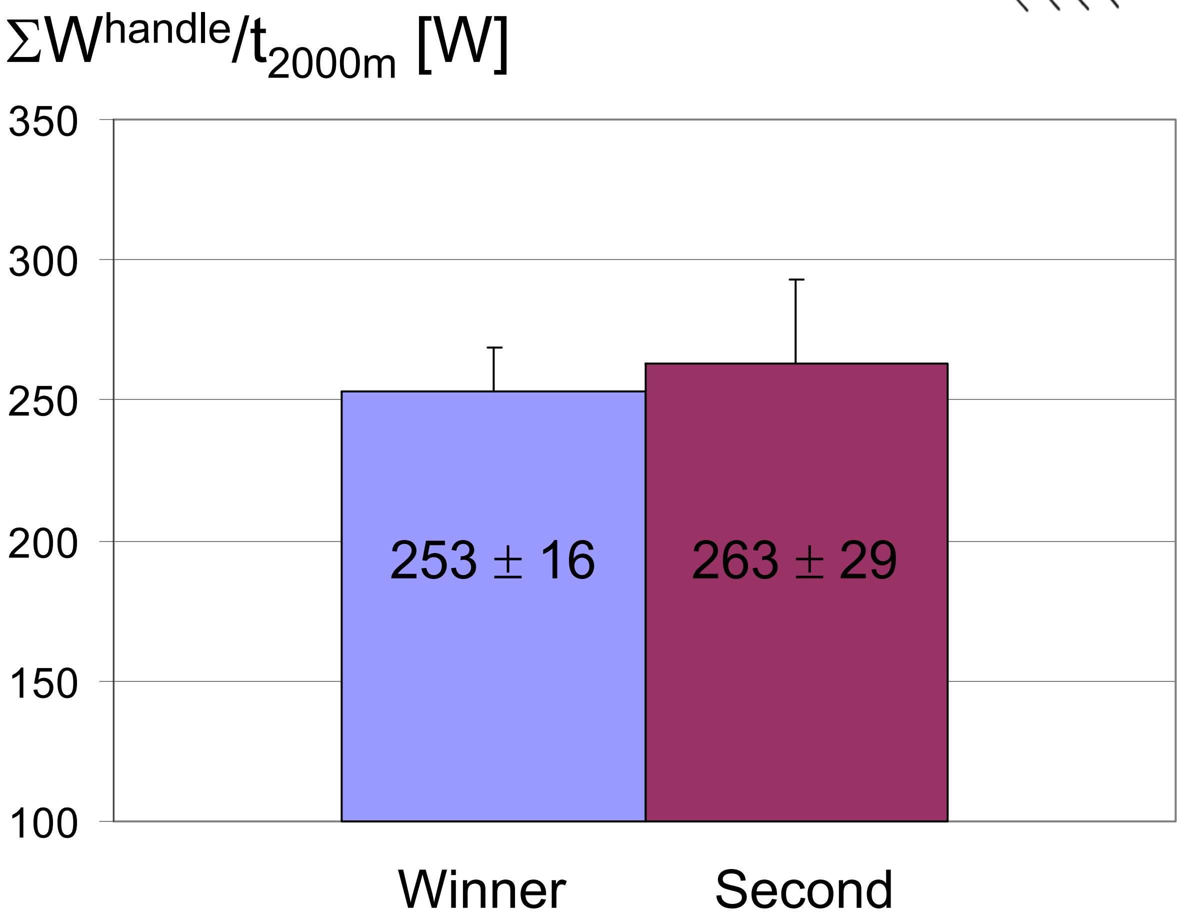
Overview of the athletes, women, n=8

Place	time [s]	number of strokes	SR [1/min]	bh [m]	bm [kg]
Second n=4	427.1	240.6	33.8±1.3	1.81 ±0.05	72.0 ±4.54
Winner n=4	425.4	234.7	33.1±1.7	1.80 ±0.04	71.5 ±5.04

Total evaluation, 2000m



Comparison winner vs. second place, race time difference < 2s

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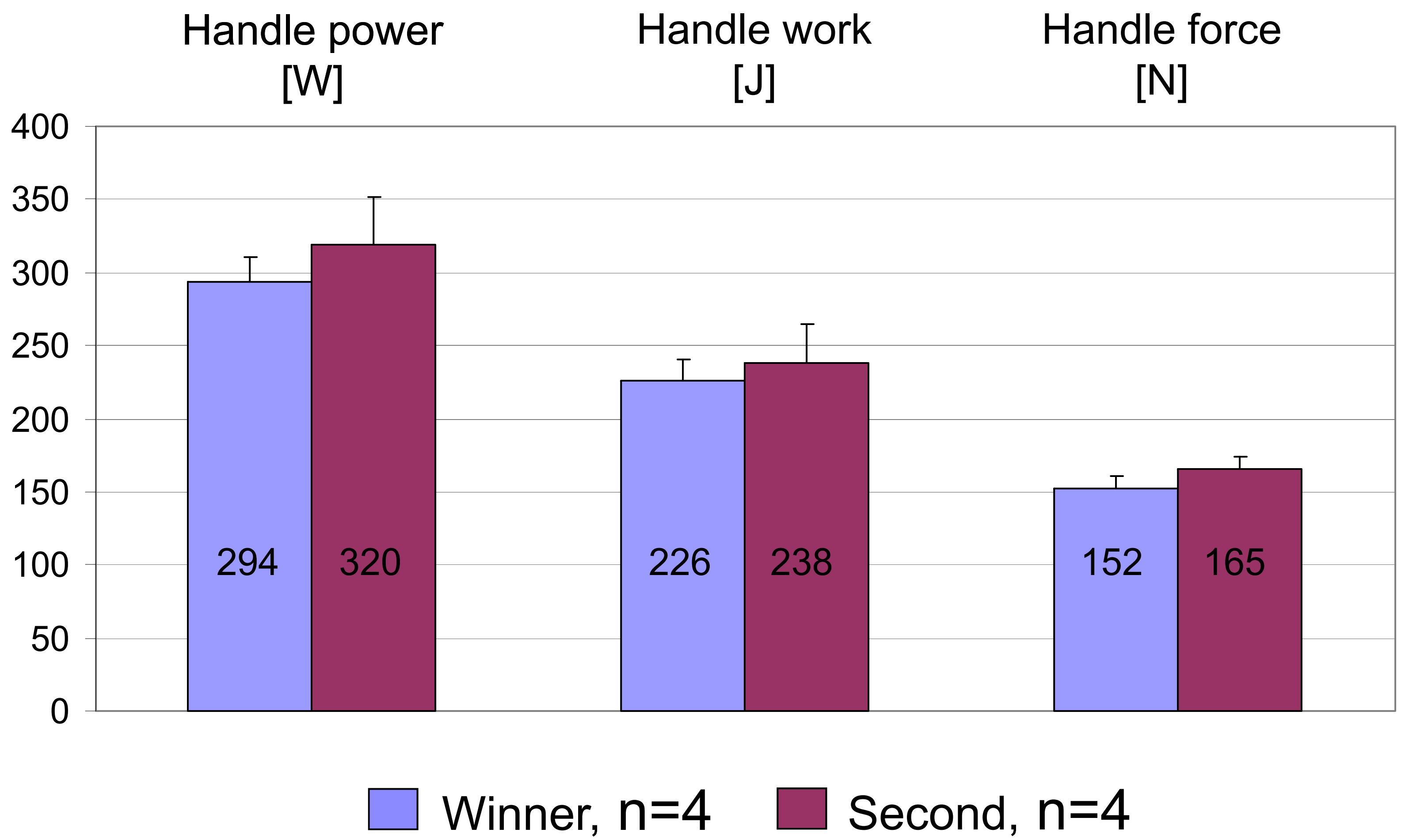
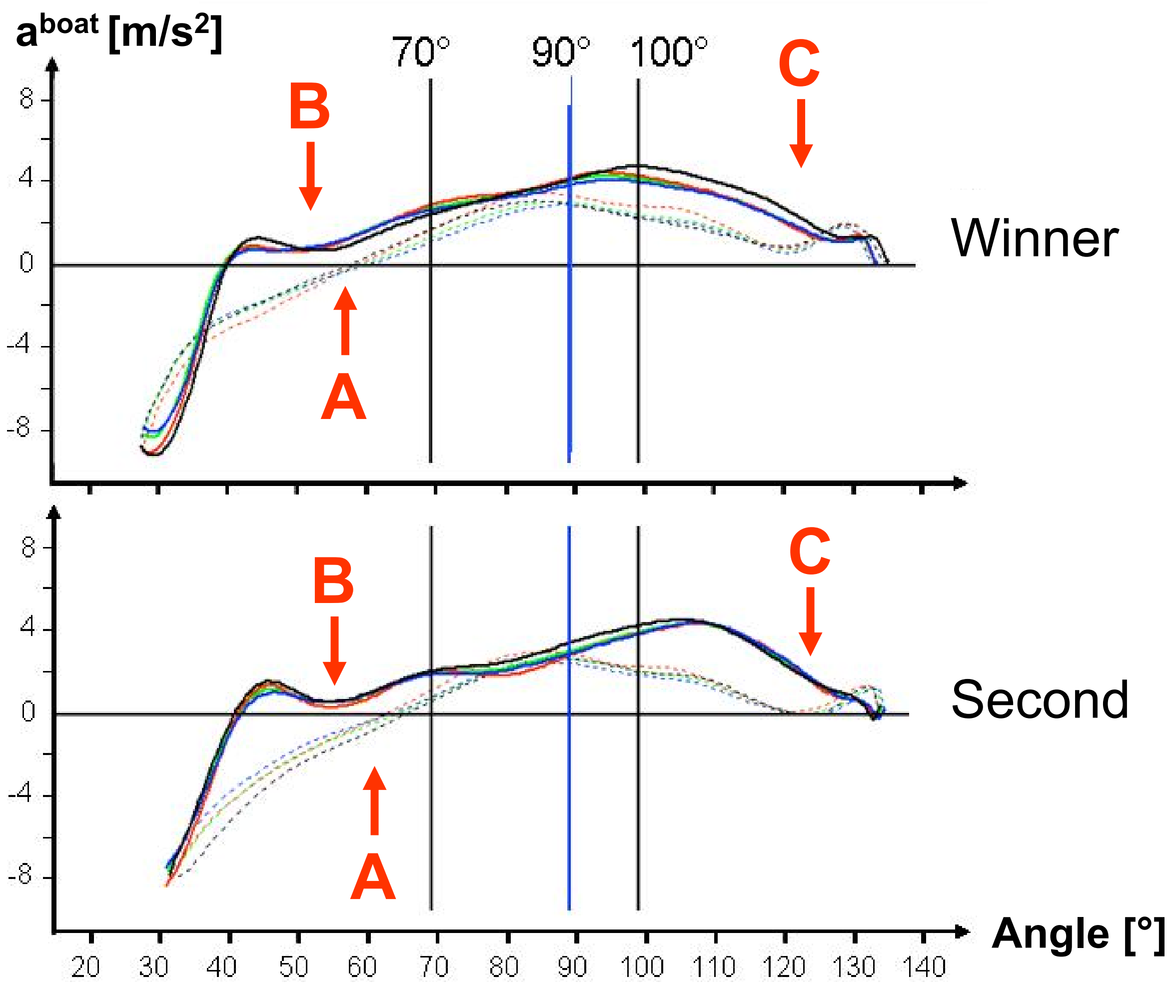


Comparison winner and second place, German Championchips 2004, W4x



What can we emphasize?

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- 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

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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

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…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

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Sculling technique

Sweep rowing technique

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Sculling technique

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

Rowing technique

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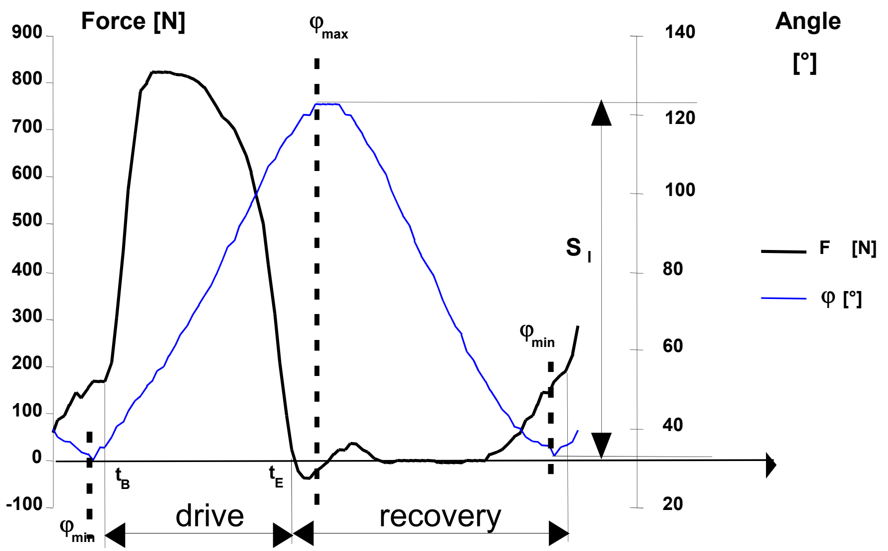
depends on

- 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_{max} = 810 N

F_{mean} = 600 N

t_{drive} = 0.72 s

Applied forces on a boat

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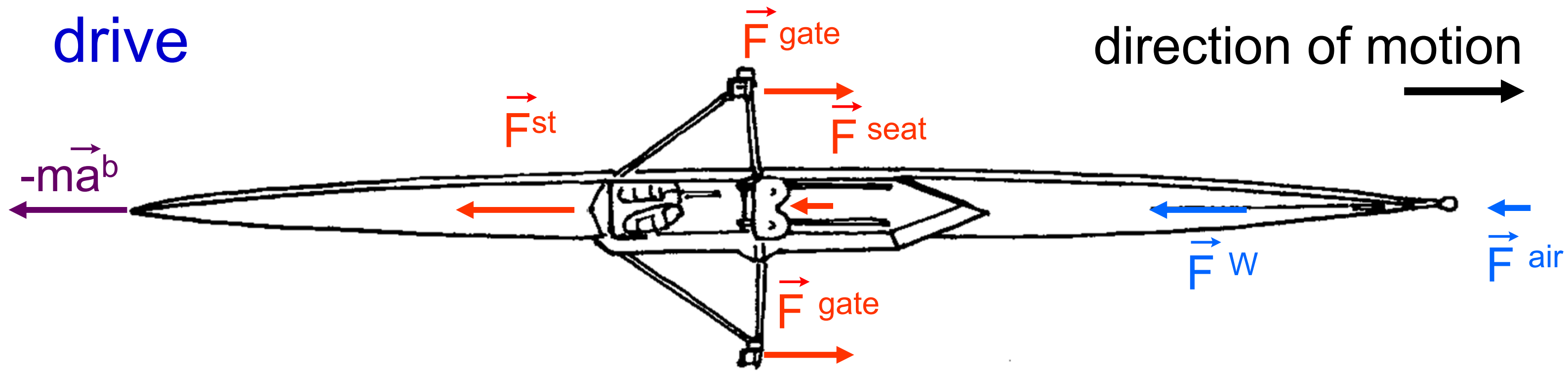

$$\vec{F}^{b} = \vec{F}^{gate} + \vec{F}^{st} + \vec{F}^{seat}$$

$$-m \cdot \vec{a}^{b} = \vec{F}^{b} + \vec{F}^{W} + \vec{F}^{air}$$

$-m\vec{a}^{b}$ = inertial force

m = mass

$\vec{a}^{b}$ = boat acceleration

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

$\vec{F}^{gate}$ = gate force

$\vec{F}^{seat}$ = seat force

$\vec{F}^{st}$ = stretcher force

$\vec{F}^{air}$ = total air drag force

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

Applied forces on a boat

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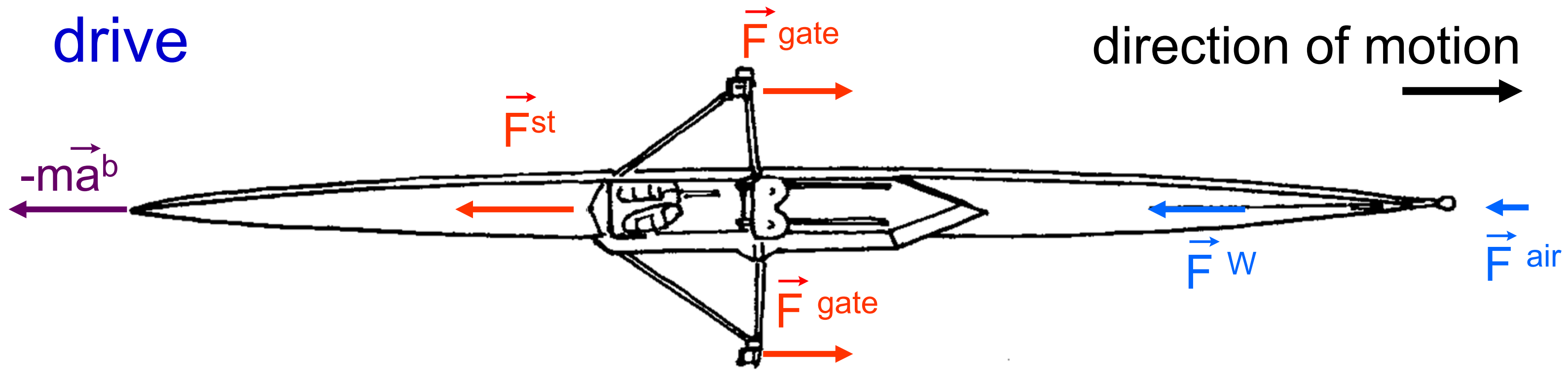

$$\vec{F}^{b} = \vec{F}^{gate} + \vec{F}^{st}$$

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Applied forces on a boat

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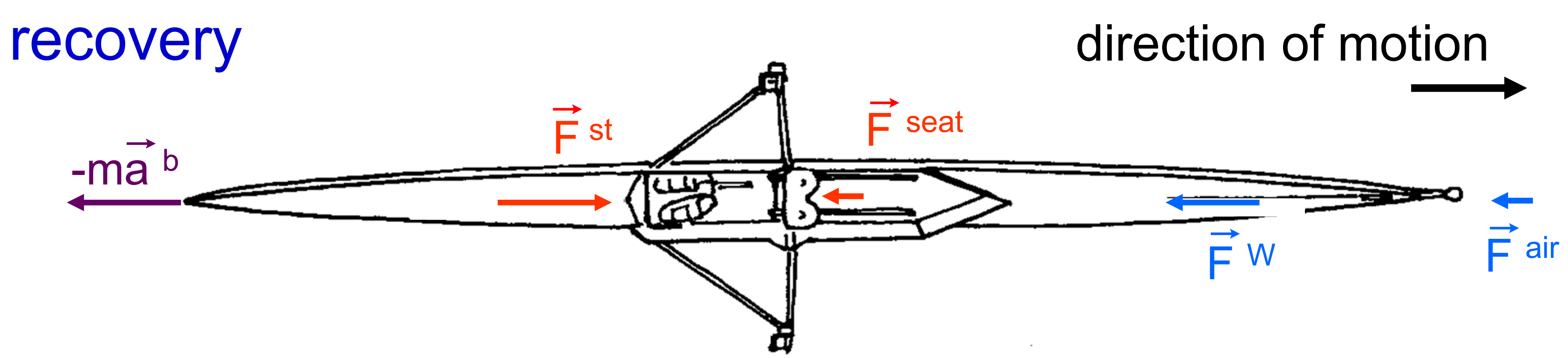

$$\vec{F}^{b} = \vec{F}^{st} + \vec{F}^{seat}$$

$$-m \bullet \vec{a}^{b} = \vec{F}^{b} + \vec{F}^{W} + \vec{F}^{air}$$

$-m\vec{a}^{b}$ = inertial force

m = mass

$\vec{a}^{b}$ = boat acceleration

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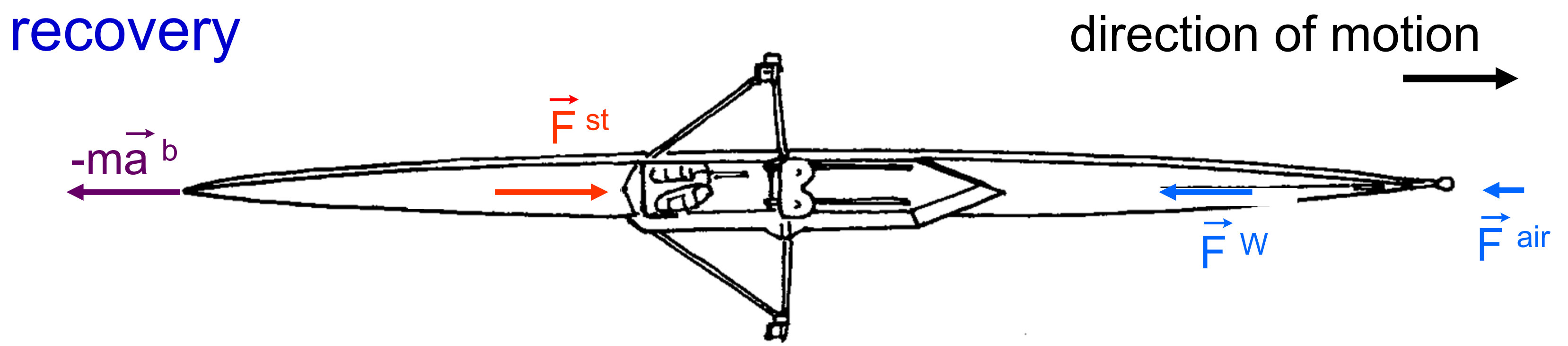
Applied forces on a boat



$$\vec{F}^{b} = \vec{F}^{st}$$

$$-m \bullet \vec{a}^{b} = \vec{F}^{b} + \vec{F}^{W} + \vec{F}^{air}$$

$-m\vec{a}^{b}$= inertial force

m = mass

$\vec{a}^{b}$= boat acceleration

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

$\vec{F}^{st}$= stretcher force

$\vec{F}^{air}$ = total air drag force

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

Comparison of curves of boat-force (F^{boat}) against boat-acceleration (a^{boat}) using a single (1x) as an example

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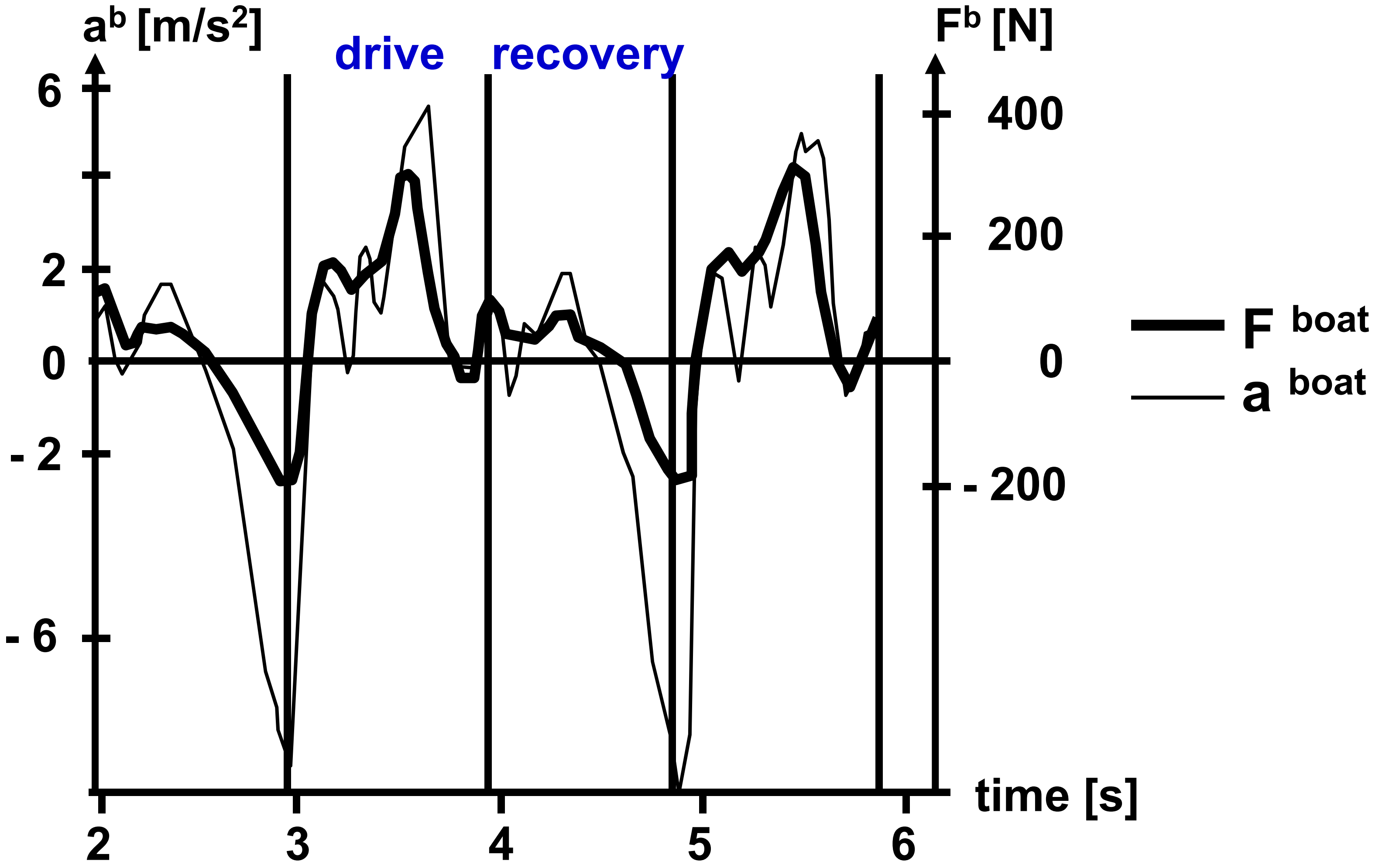

Force-angle curves, four rowers, same stroke rate

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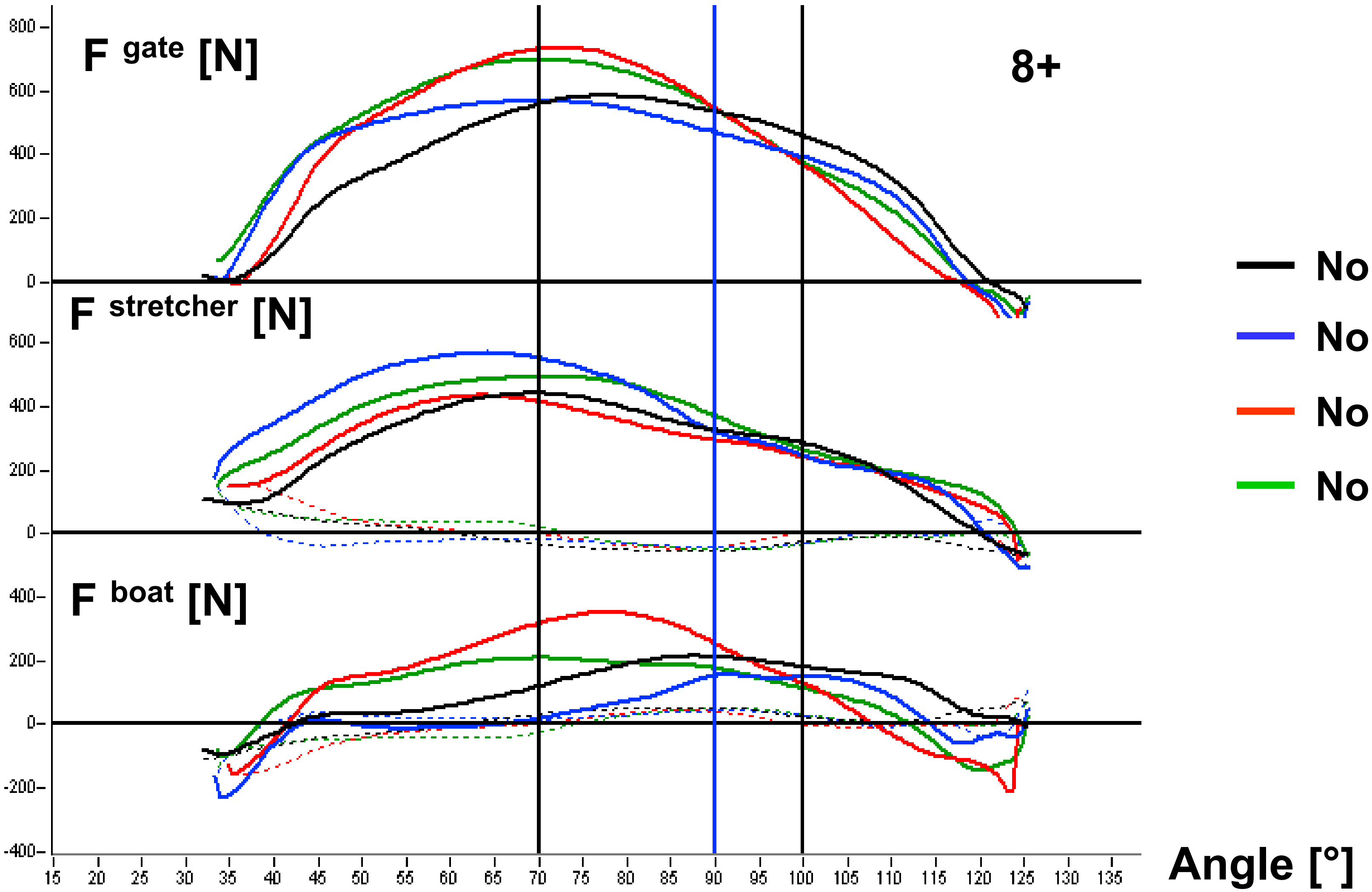

Force-angle curves, one rower, different stroke rates

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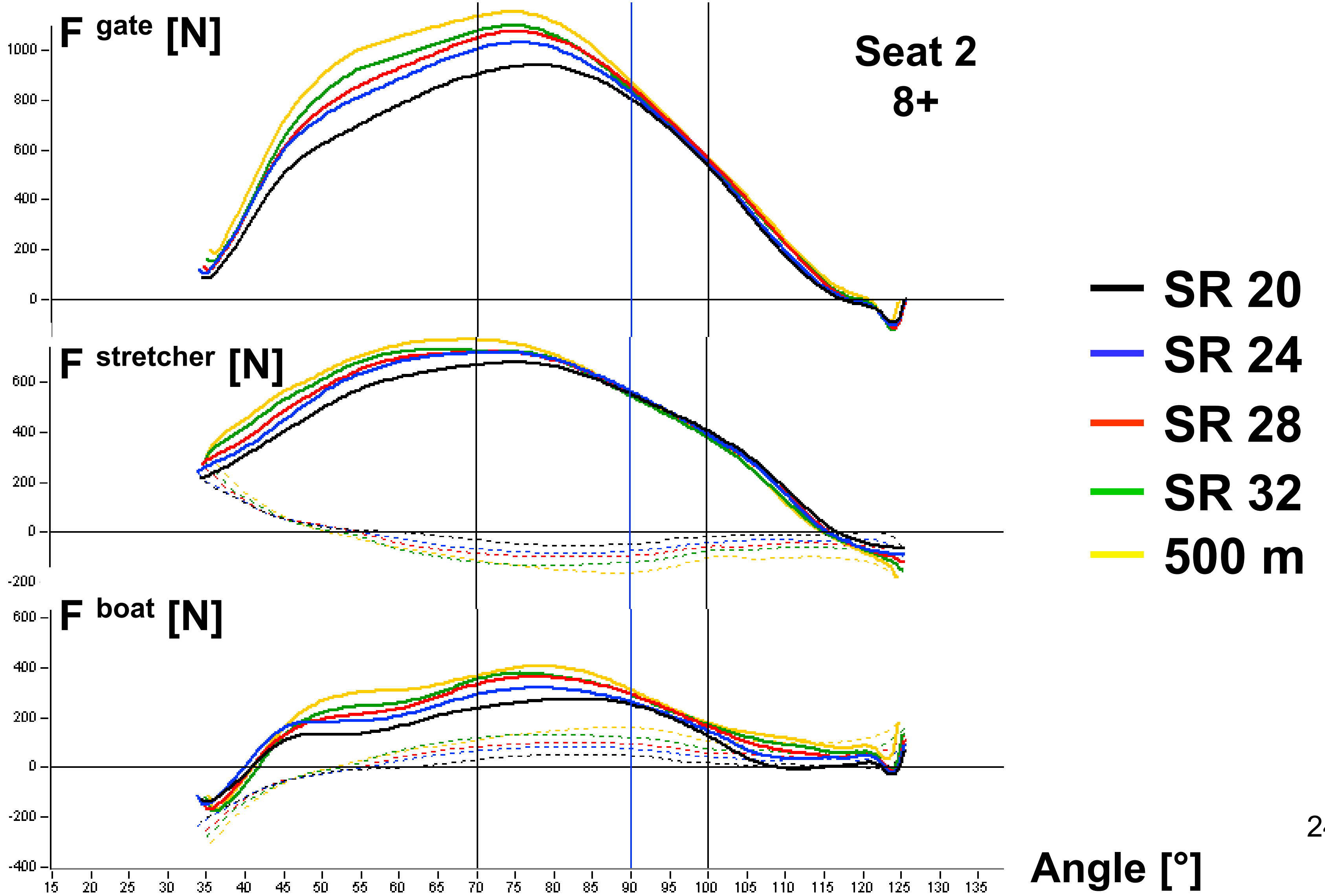

Force-angle curves, one rower, different stroke rates

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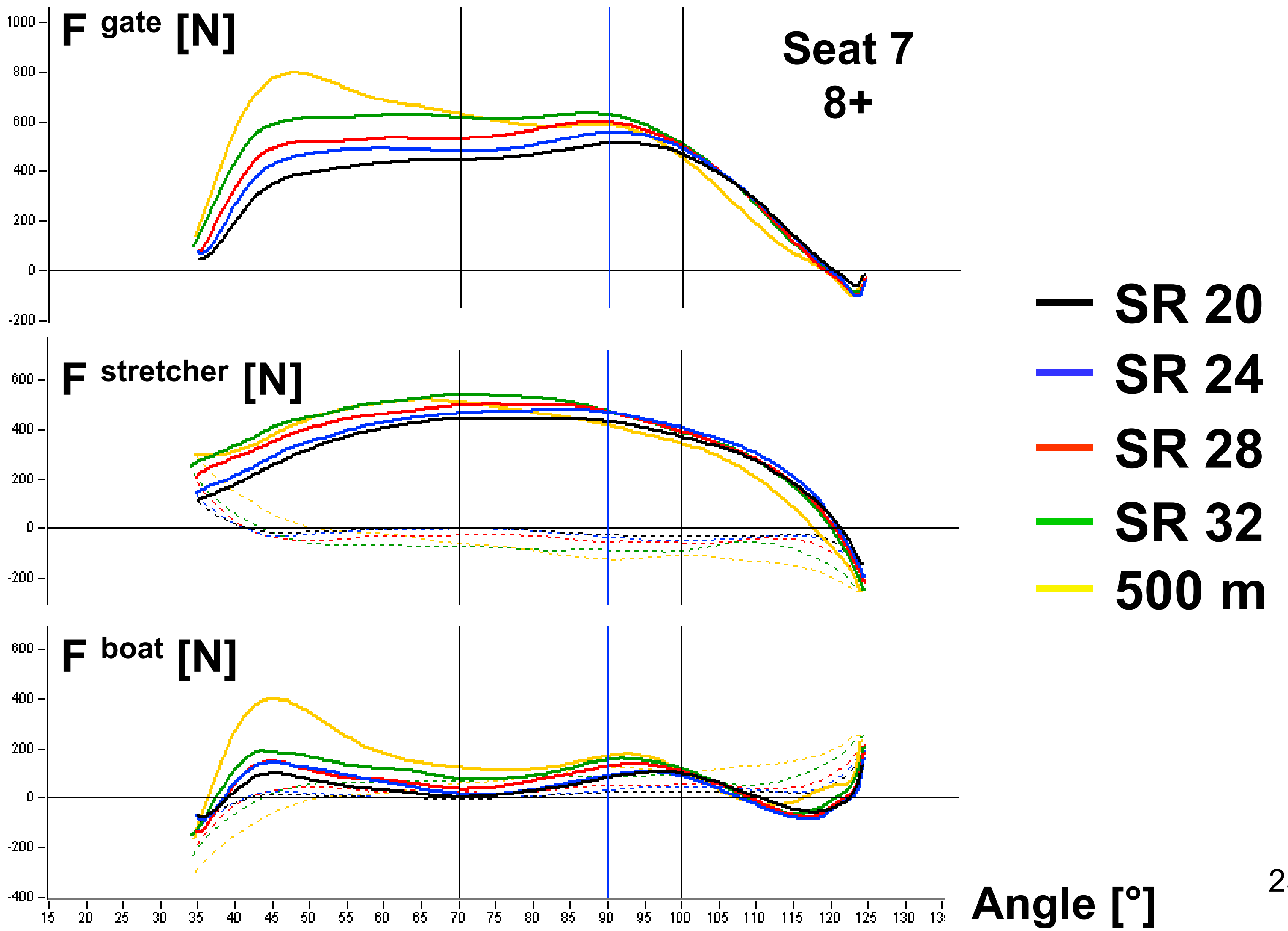

Synchronisation of video and biomechanical data

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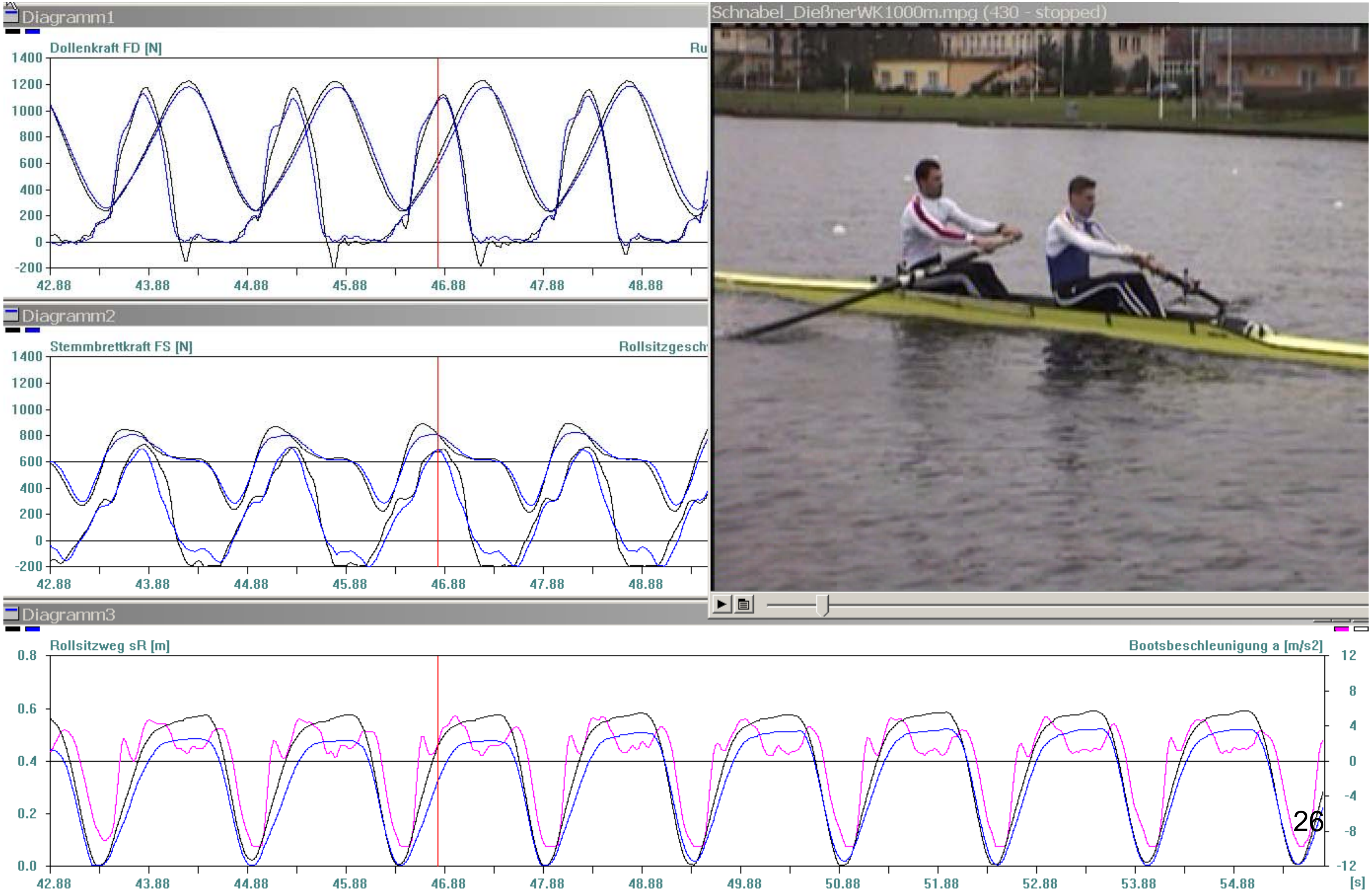

Important aspects of rowing technique

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

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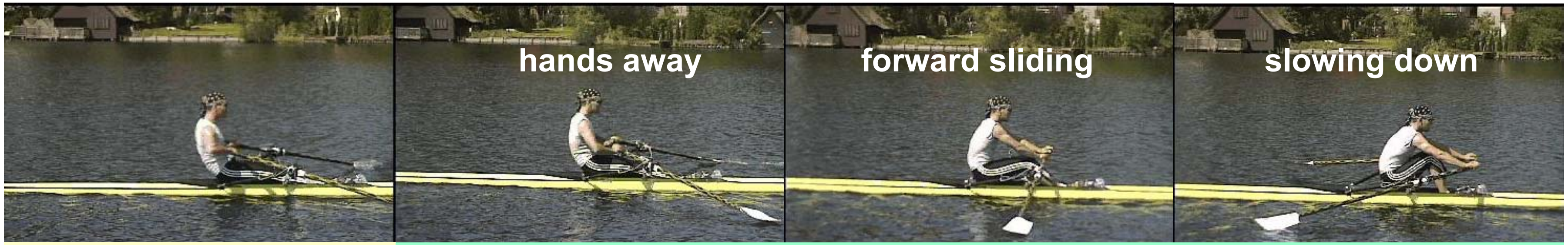
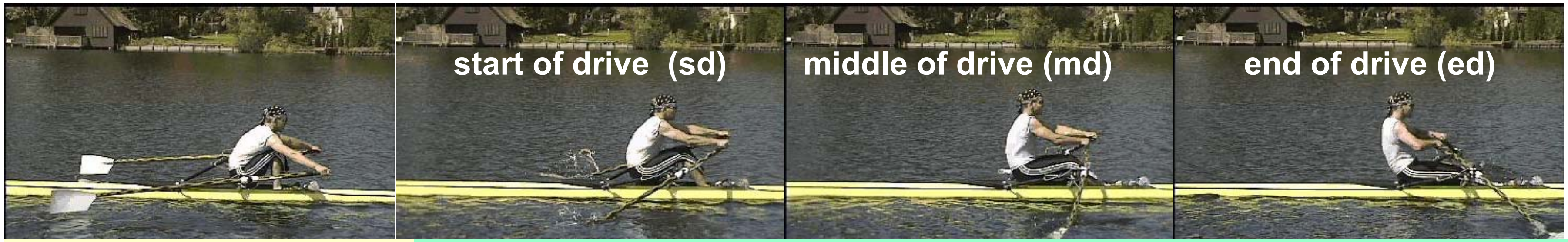


rear reversal | recovery



front reversal | drive

Structure

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Biomechanical parameters of rowing power and technique

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parameters and characteristic curves

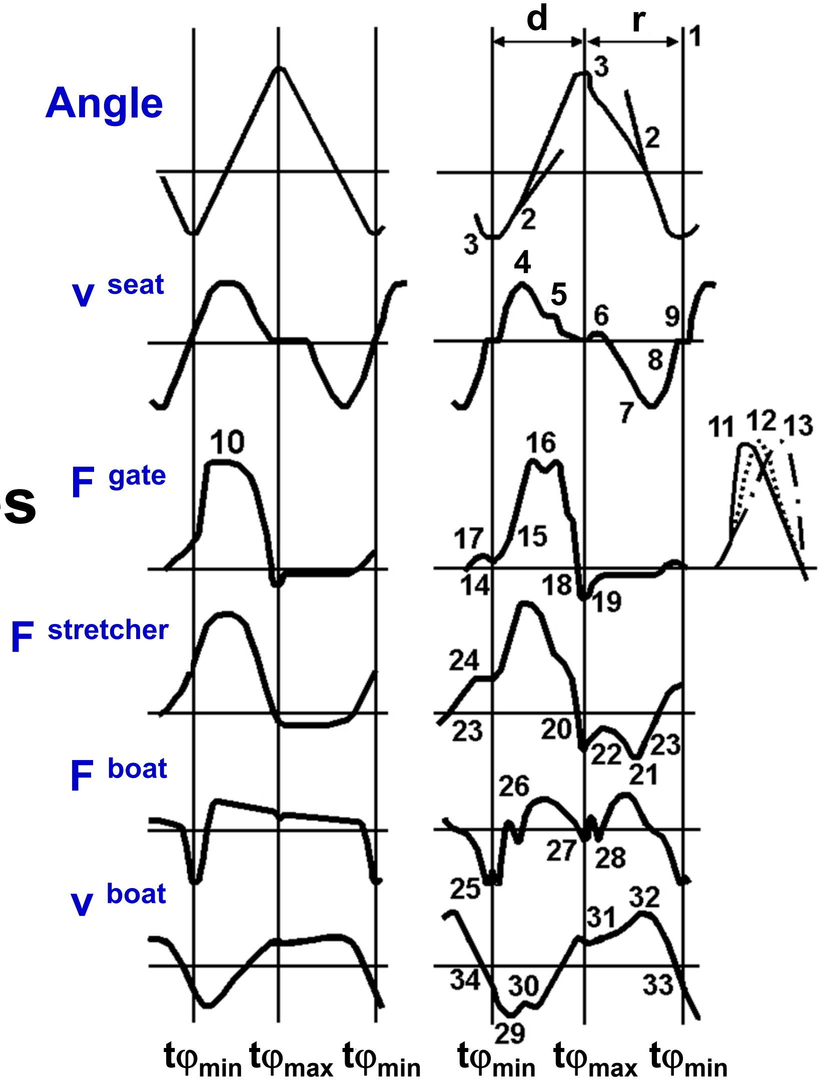
	kinematic	dynamic
individual parameter	oar angle (φ) oar velocity (v^{handle}) seat position (s^{seat}) seat velocity (v^{seat})	handle force (F^{handle}) gate force (F^{gate}) stretcher force ($F^{stretcher}$) boat force (F^{boat})
crew parameter	boat acceleration (a^{boat}) boat velocity (v^{boat})	

Comparison of biomechanical curves for rowing technique

d = drive

r = recovery

ideal curves



curves with error illustrations

Rowing angle and stroke phases

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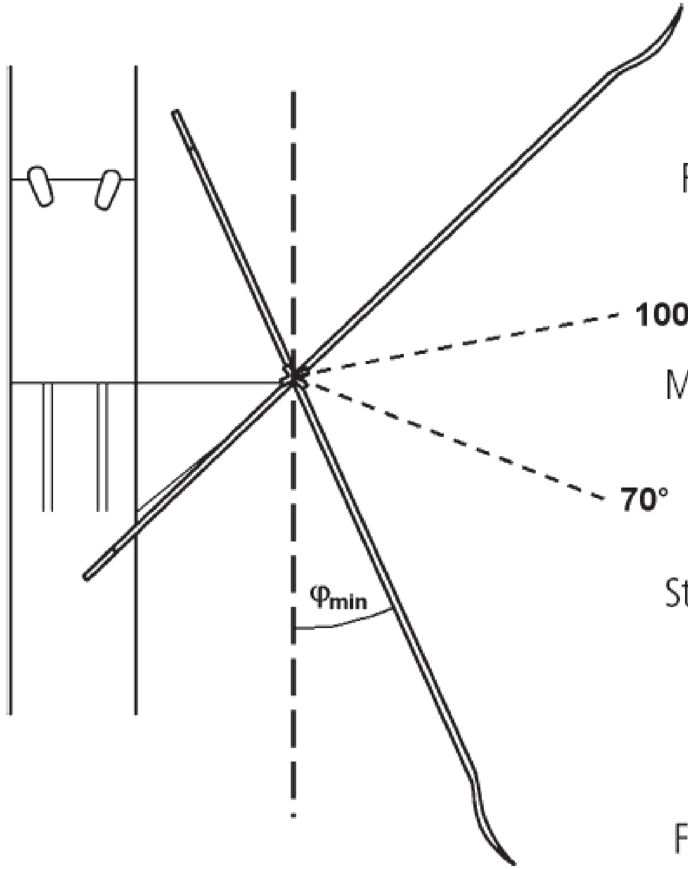

Rowing movement structure

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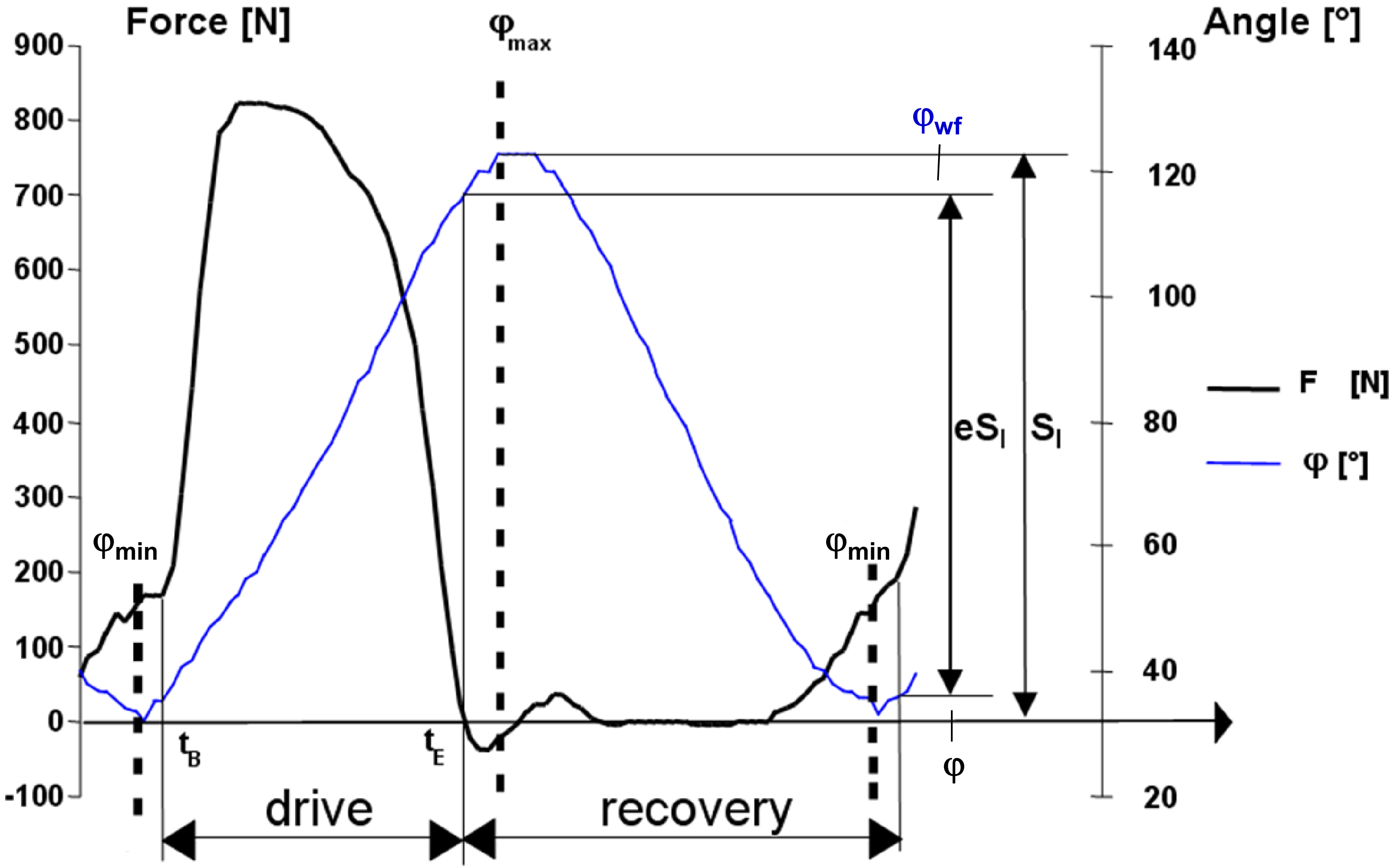

Characteristic oar angle-time curves

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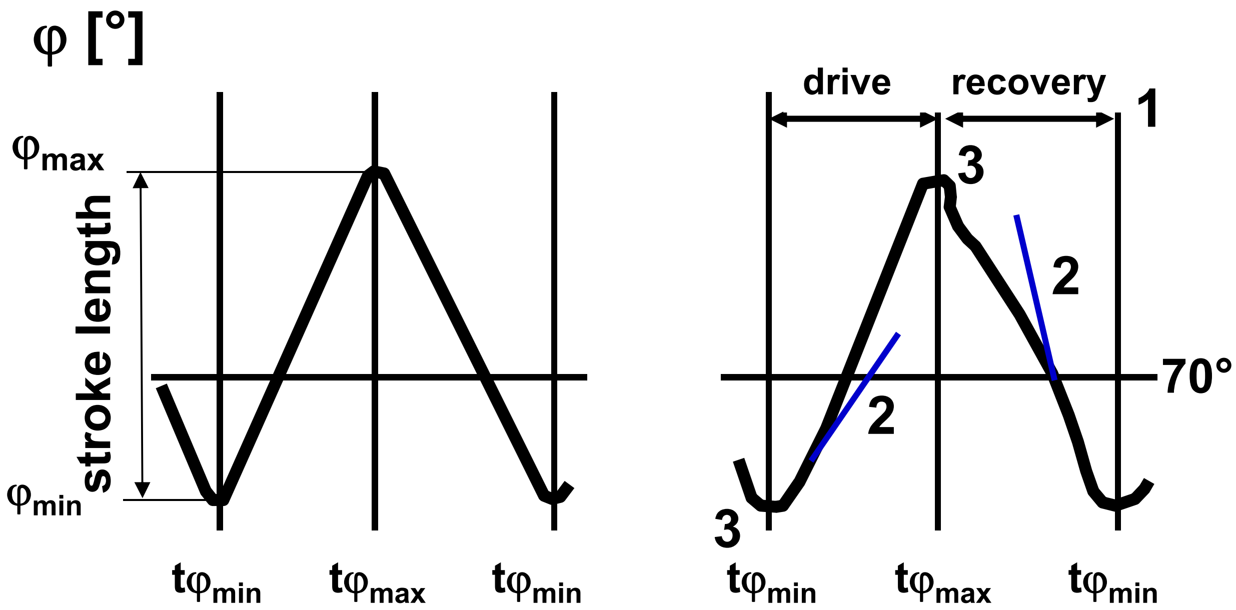
ideal curves / **curves with error illustrations**



- 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

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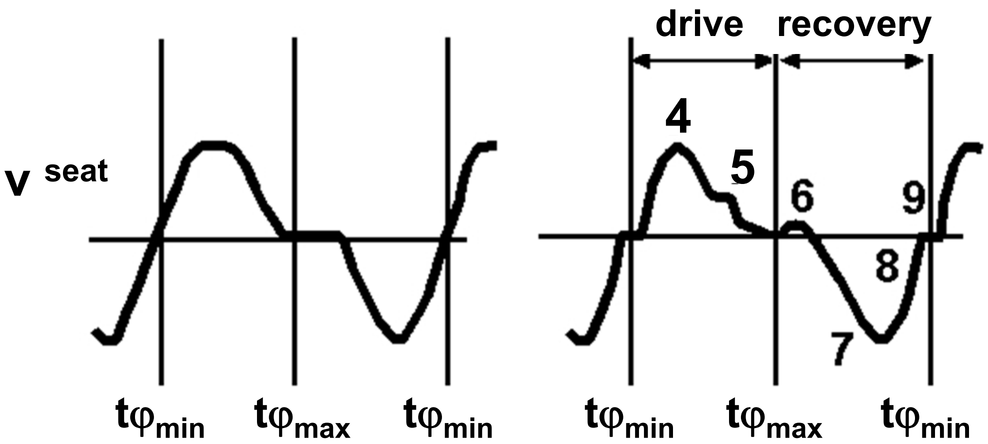
ideal curves **curves with error illustrations**



- 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

Data	Sl [°]	φ_i [°]	φ_{wc} [°]	t_{wc} [s]	φ_x [°]	φ_{wf} [°]	t_{wf} [s]	S^{seat}_{cycle} [m]	S^{seat}_{drive} [m]
M1x	110	24	1	0.04	134	3	0.07	0.6	0.53
M2x	110	24	1	0.04	134	3	0.07	0.6	0.53
M4x	110	24	1	0.04	134	3	0.07	0.6	0.53
LM2x	106	28	1	0.04	134	3	0.07	0.54	0.5
M2-	90	36	1.5	0.05	126	4	0.09	0.6	0.54
M4-	90	36	1.5	0.05	126	4	0.09	0.6	0.54
M8+	90	36	1.5	0.05	126	4	0.09	0.6	0.54
LM4-	86	38	1.5	0.05	124	4	0.09	0.56	0.5

Stroke length, stroke angles and seat position

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Senior women average values over 2000m

Data	Sl [°]	φ_i [°]	φ_{wc} [°]	t_{wc} [s]	φ_x [°]	φ_{wf} [°]	t_{wf} [s]	S^{seat}_{cycle} [m]	S^{seat}_{drive} [m]
unit	°	°	°	**s**	°	°	**s**	**m**	**m**
W1x	106	28	1	0.04	134	3	0.07	0.52	0.48
W2x	106	28	1	0.04	134	3	0.07	0.52	0.48
W4x	106	28	1	0.04	134	3	0.07	0.52	0.48
LW2x	102	30	1	0.04	132	3	0.07	0.48	0.44
W2-	86	36	1.5	0.05	122	4	0.09	0.5	0.46
W8+	86	36	1.5	0.05	122	4	0.09	0.5	0.46

Synchronisation of video and biomechanical data

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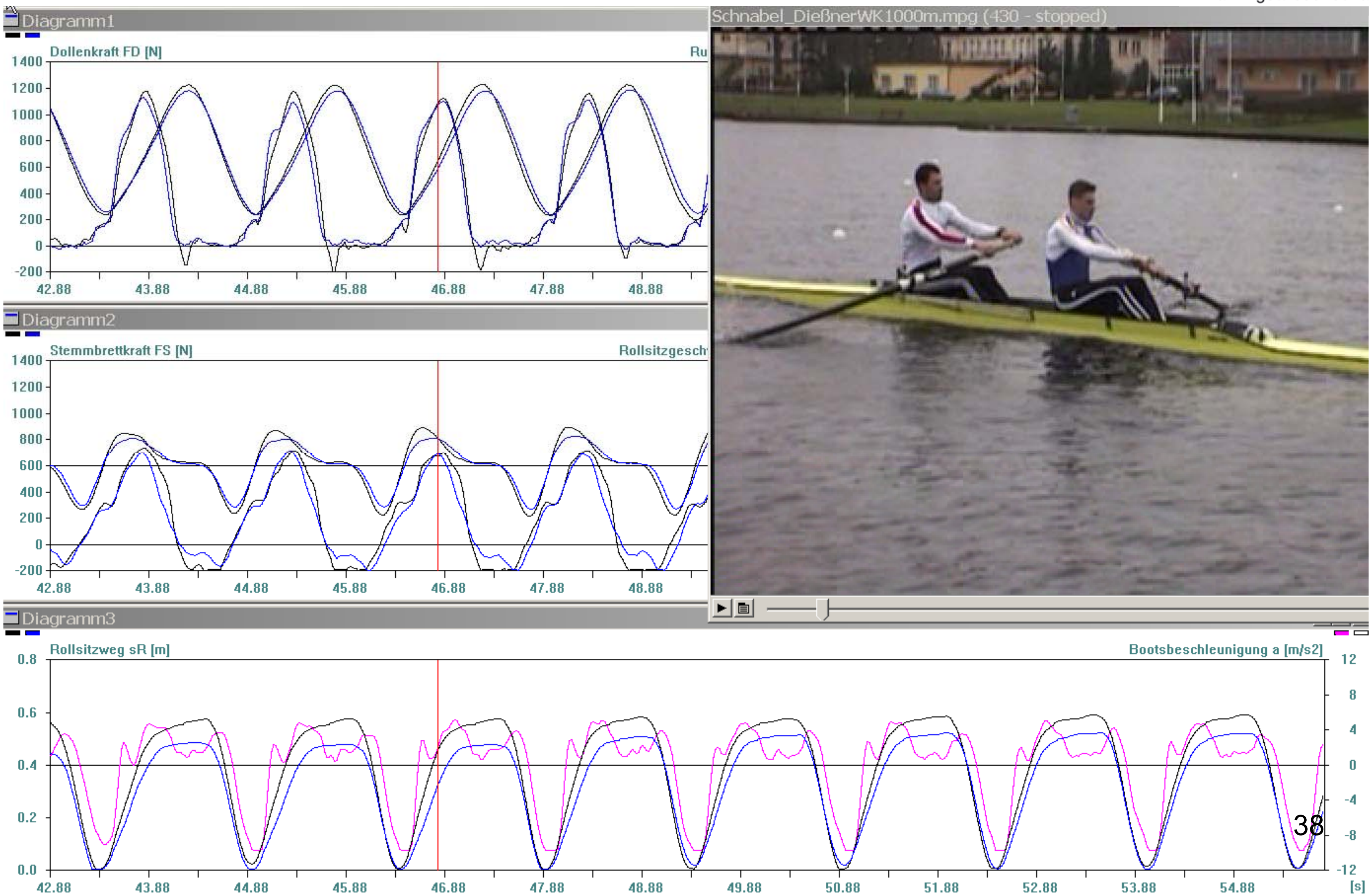
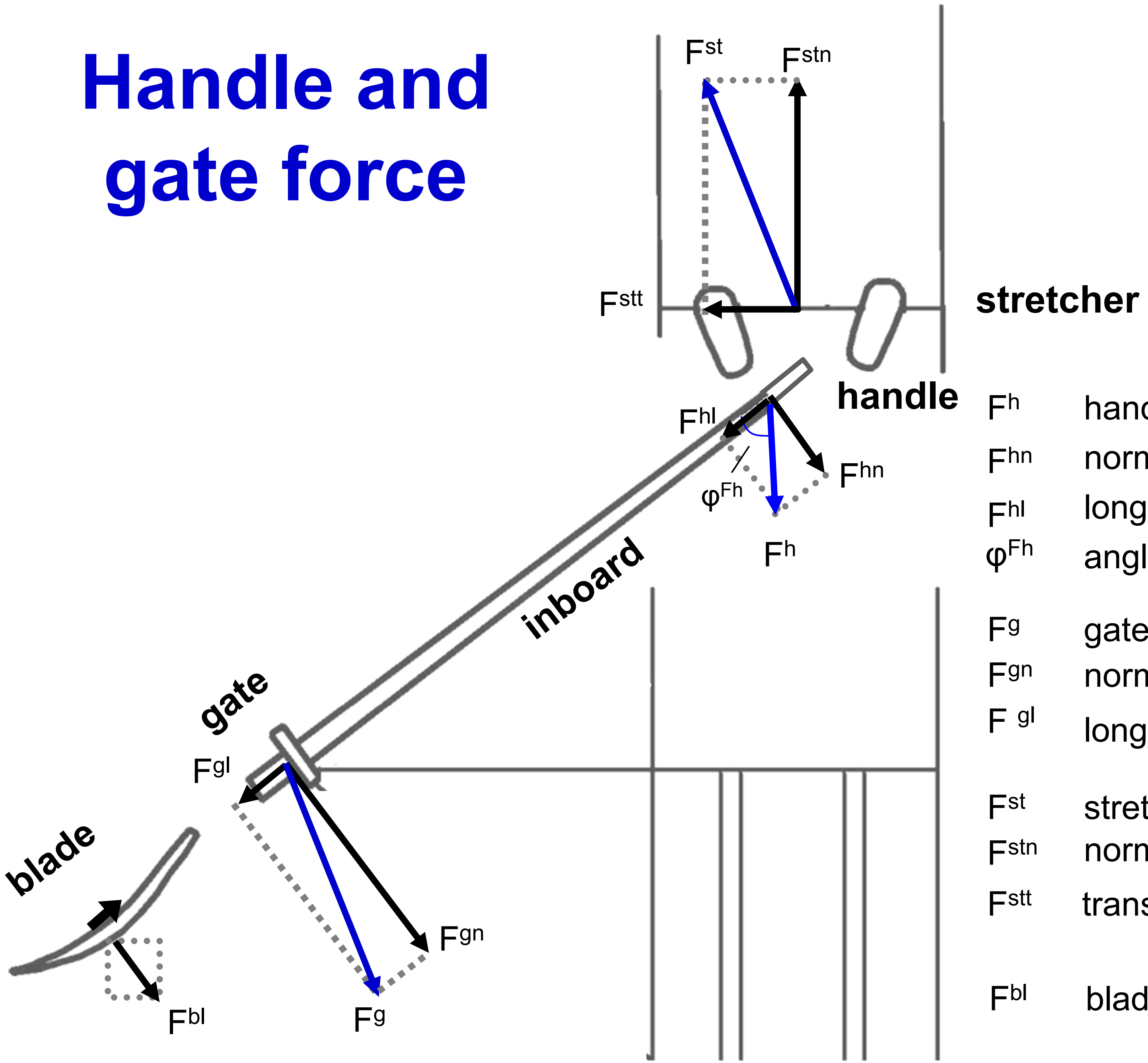


Handle and gate force



F^{h} handle-force
F^{hn} normal component
F^{hl} longitudinal component
φ^{Fh} angle of pull direction

F^{g} 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

Characteristic handle force-time curves

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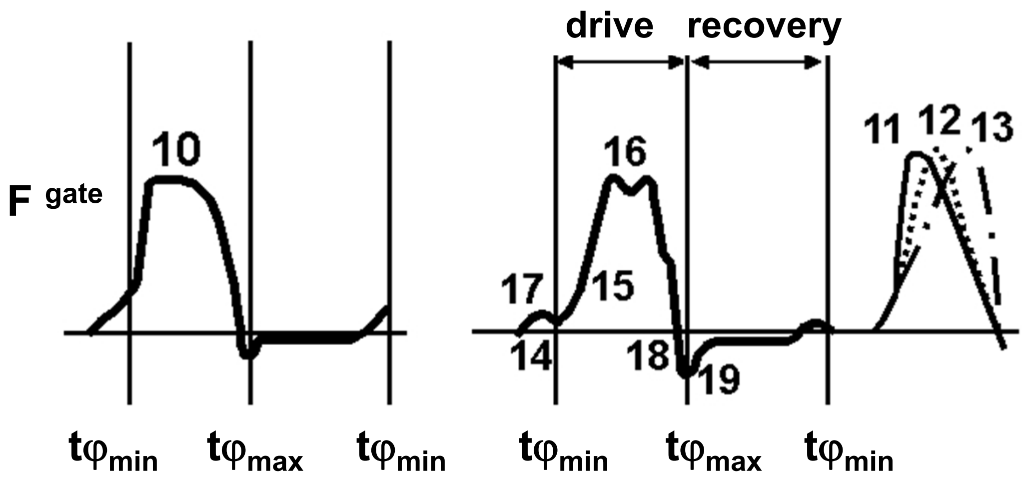
ideal curves **curves with error illustrations**



- 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

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Senior men on average over 2000m

Data		cycle		drive					
	bh	**SR**	**P_{handle}**	**P_{handle}**	**W_{handle}**	**F_{handle}**	**v_{handle}**	**t_{drive}**	**s_{handle}**
unit	m	1/min	W	W	J	N	m/s	s	m
M1x	1.96	37	505-605	1040-1300	820-980	520-620	2.00-2.10	0.66-0.70	1.58
M2x	1.96	38	510-610	1035-1300	805-960	510-610	2.03-2.13	0.64-0.67	1.58
M4x	1.96	39	520-620	1025-1290	800-940	500-600	2.05-2.15	0.62-0.65	1.58
LM2x	1.84	38	385-480	810-1065	610-760	400-500	2.03-2.13	0.64-0.70	1.52
M2-	1.98	38	380-475	800-1050	590-740	400-500	2.00-2.10	0.66-0.70	1.50
M4-	1.98	39	385-485	810-1065	580-730	395-495	2.05-2.15	0.64-0.67	1.50
M8+	1.98	40	390-490	820-1080	575-725	390-490	2.10-2.20	0.60-0.63	1.50
LM4-	1.87	39	315-415	700-965	480-640	340-450	2.05-2.15	0.64-0.67	1.42

Typical values of the handle power and its components

UH Bewegungs-& Trainingswissenschaft

Senior women on average over 2000m

Data	bh	cycle		drive					
		SR	P handle	P handle	W handle	F handle	v handle	t drive	s handle
unit	m	1/min	W	W	J	N	m/s	s	m
W1x	1.80	35	480-570	550-780	430-580	290-390	1.90-2.00	0.68-0.71	1.48
W2x	1.80	37	255-350	540-770	415-560	280-380	1.92-2.02	0.66-0.69	1.48
W4x	1.80	38	260-360	545-780	415-560	280-380	1.95-2.05	0.64-0.67	1.48
LW2x	1.68	36	205-265	460-625	340-440	240-310	1.92-2.02	0.62-0.65	1.42
W2-	1,82	36	250-320	570-760	420-530	300-380	1.90-2.00	0.66-0.69	1.40
W8+	1.82	38	260-330	580-780	410-520	290-370	2.00-2.1	0.62-0.65	1.40

Evaluation of the handle power

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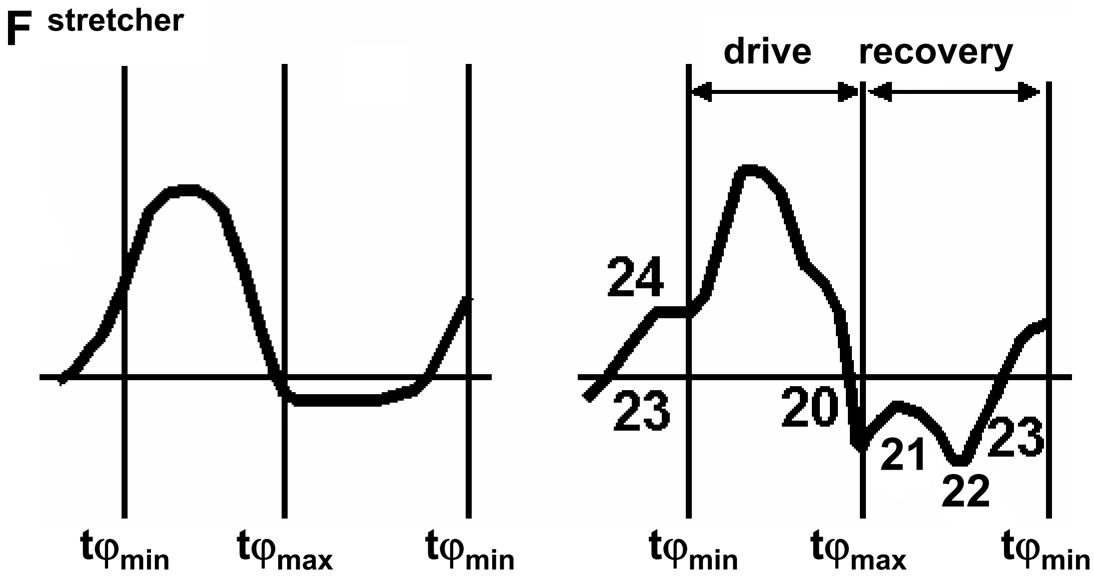
Total evaluation	Handle power in the stroke cycle (e.g. over 2000m)	P^{handle}_{cycle}
direct effect	• stroke rate • handle power in the drive phase • handle work in the drive phase • handle force in the drive phase • handle velocity in the drive phase • effective stroke length • drive time	SR W_{handle} F_{handle} s_{handle} v_{handle} Sl t_{drive}
indirect effect and details	• handle force in - start of drive - middle of drive - finsh of drive • handle velocity in - start of drive - middle of drive - finsh of drive • stroke length - minimal angle - maximal angle • seat velocity in the drive phase - start of drive - middle of drive	F_{handle} v_{handle} s_{l} φ_{min} φ_{max} v_{seat}

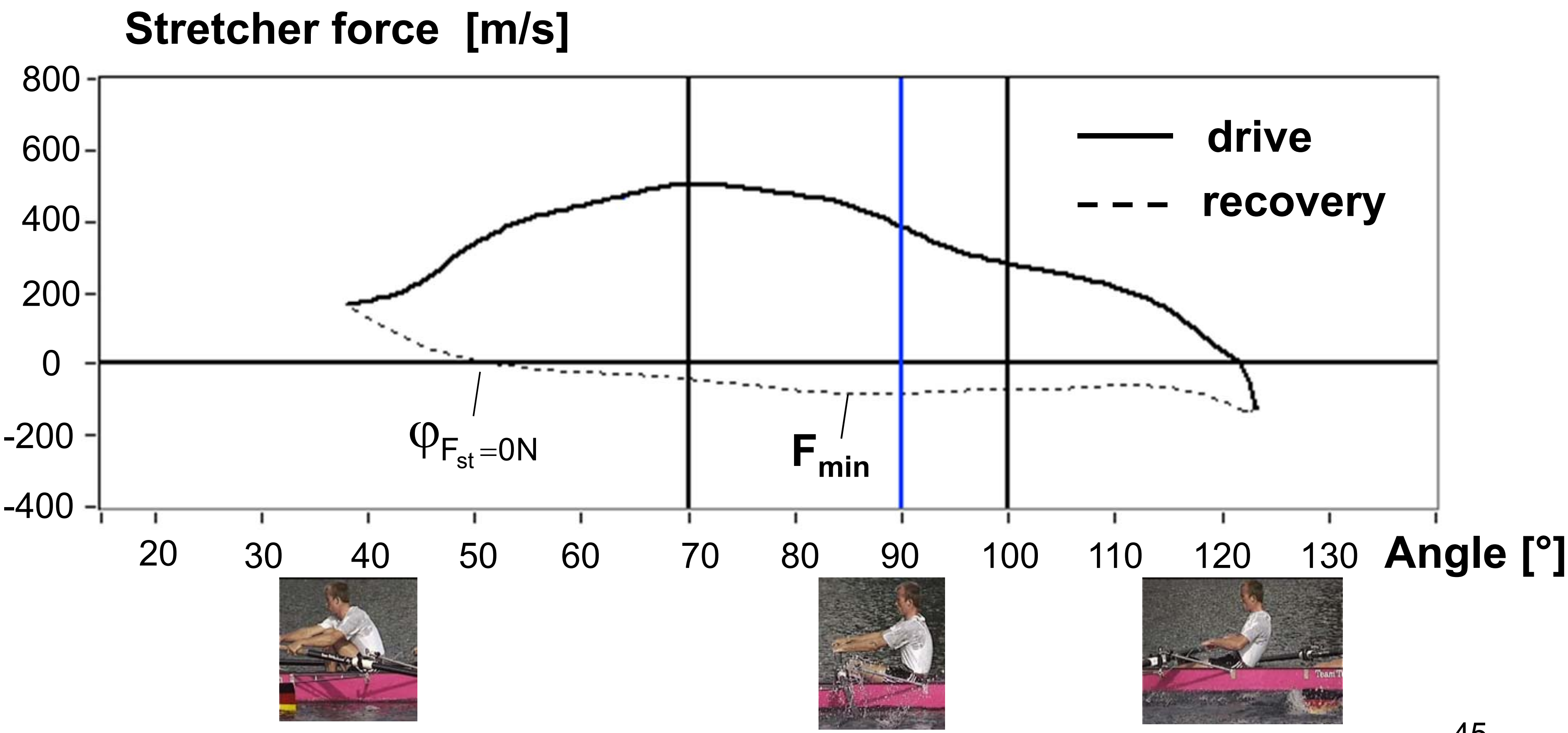
Characteristic stretcher force-time curves

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 ($F^{stretcher}$) recovery



Evaluation of the recovery phase through stretcher force and seat velocity values

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Characteristics of the recovery phase		
direct effect	• minimum of the stretcher force in the recovery [N]	$V^{stretcher}_{min}$
	• oar angle to the point of zero stretcher force (Chance the stretcher force of pull to pressure force in the recovery) [°]	$\varphi_{F_{st}=0N}$
	• average seat velocity in the recovery [m/s]	V^{seat}
indirect effect and details	• seat displacement [m]	S^{seat}
	• minimal seat velocity in the recovery (maximum of the seat velocity in the forward direction) [m/s]	V^{seat}_{min}

Characteristic boat force-time curves

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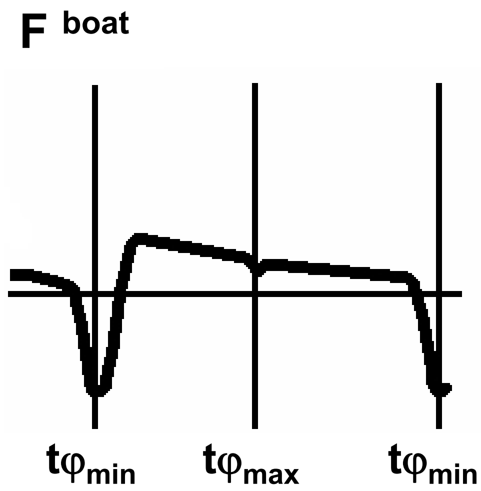
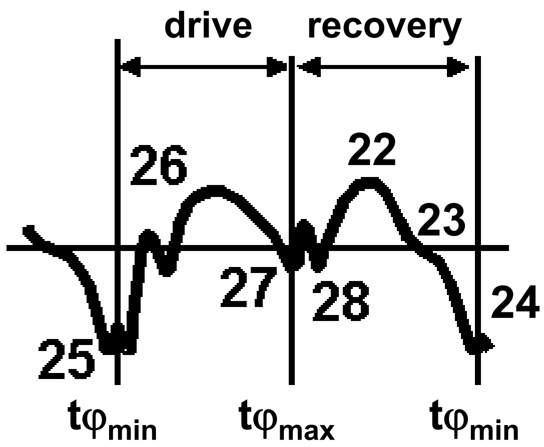
ideal curves **curves with error illustrations**





- 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

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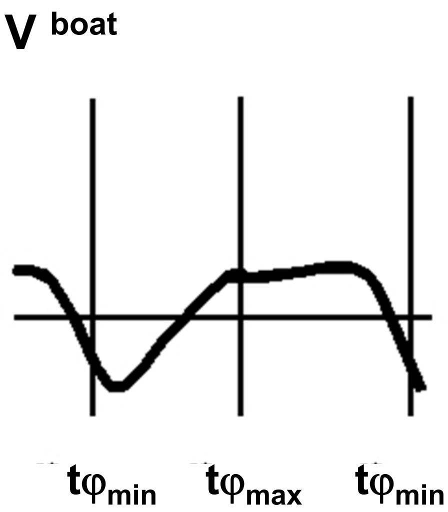
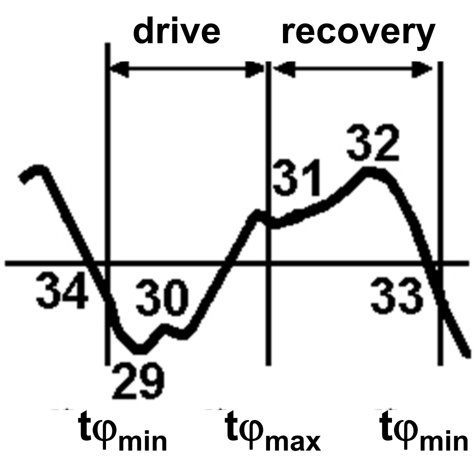
ideal curves | **curves with error illustrations**





- 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^{boat})

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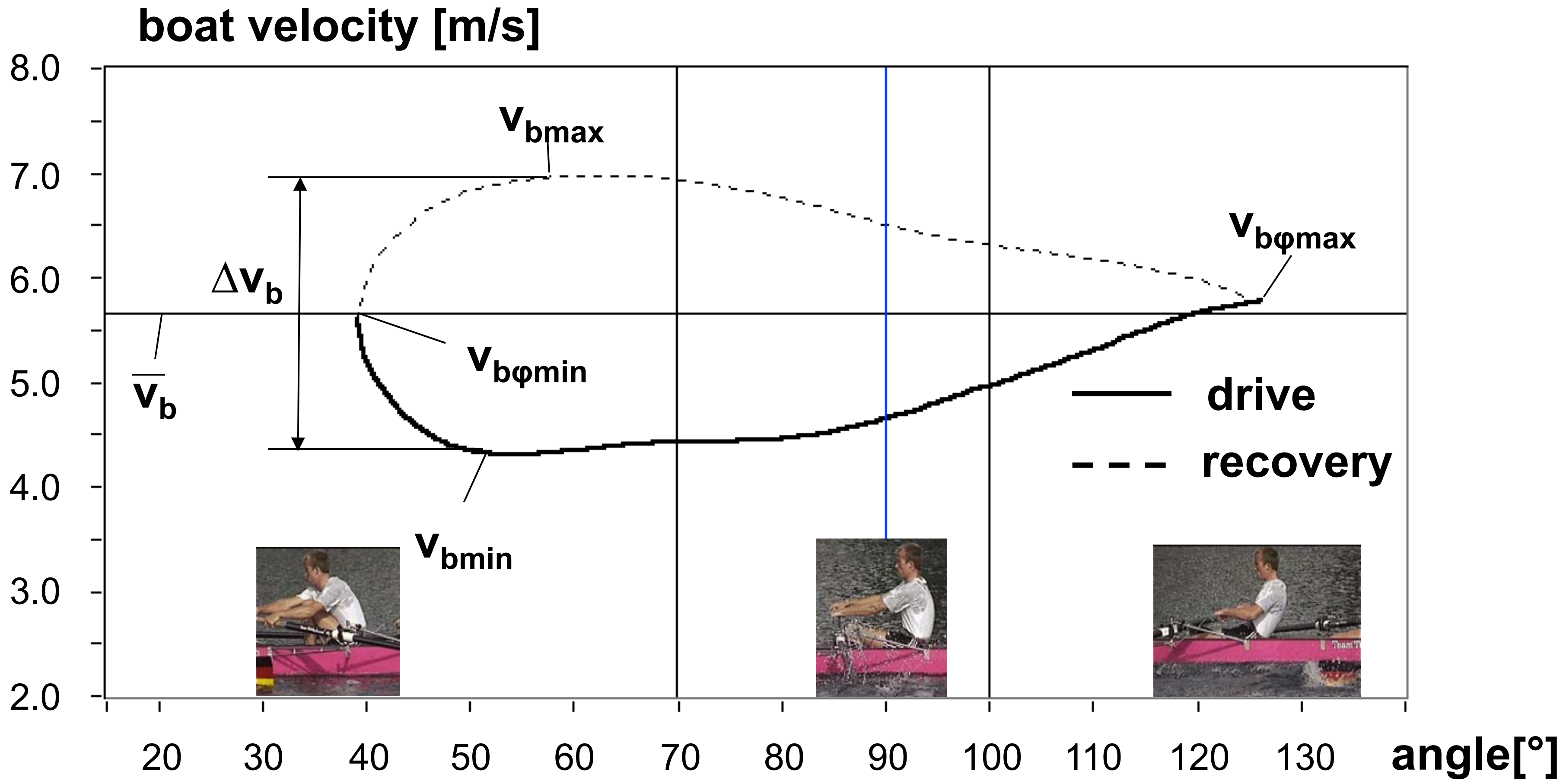

Test	Strokes	SR [1/min]	s_b [m]	v_b [m/s]	v_{bmin} [m/s]	v_{bmax} [m/s]	Δv_b [m/s]	Δv_b [%]	$v_{b\varphi min}$ [m/s]	$v_{b\varphi max}$ [m/s]
0047	209	36.9	9.24	5.66	4.29	5.62	2.68	47.6	5.62	5.77

Characteristic values (v^{boat})

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Boat velocity depends on the stroke rate (SR)

Test	Strokes	SR [1/min]	s_b [m]	v_b [m/s]	v_{bmin} [m/s]	v_{bmax} [m/s]	Δv_b [m/s]	Δv_b [%]	$v_{b\varphi min}$ [m/s]	$v_{b\varphi max}$ [m/s]
0047	10	20.0	12.65	4.21	3.18	4.32	1.44	34.2	3.92	4.49
0047	10	24.5	11.57	4.72	3.60	4.78	1.73	36.8	4.50	4,97
0047	10	29.2	10.51	5.12	3.95	5.14	2.04	39.9	4.88	5.33
0047	209	36.9	9.24	5.66	4.29	5.62	2.68	47.6	5.62	5.77

Evaluation of boat velocity fluctuation

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Total evaluation	• average boat velocity [m/s] • innercycle boat velocity fluctuation – absolute [m/s] – as a percentage of the average boat velocity [%]	v^{boat} Δv^{boat}
direct effect	• stroke rate [1/min] • minimum boat velocity [m/s] • maximum boat velocity [m/s]	SR v^{boat}_{min} v^{boat}_{max}
indirect effect and details	• boat velocity during minimum oar angle [m/s] • boat velocity during maximum oar angle [m/s]	$v^{boat}_{\varphi max}$ $v^{boat}_{\varphi min}$

The diagnosis of rowing technique faults

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- 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.

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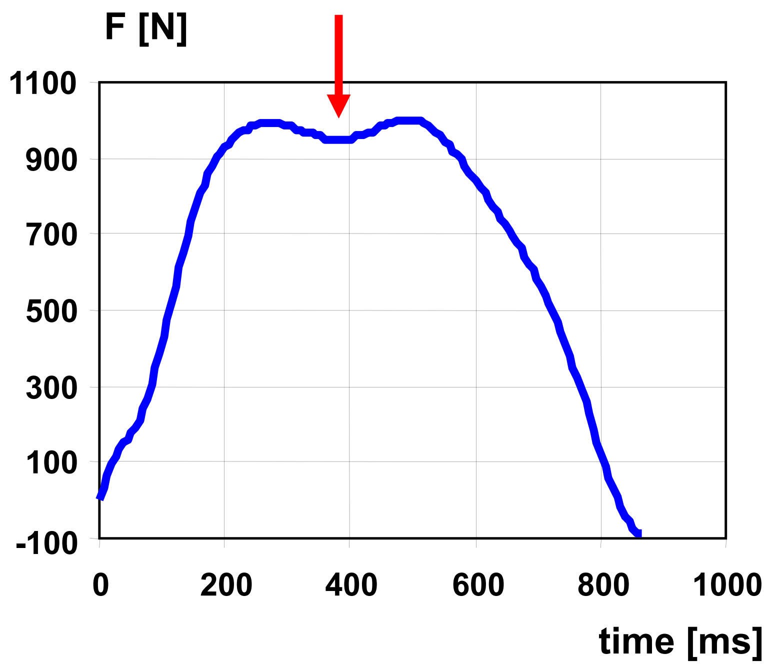
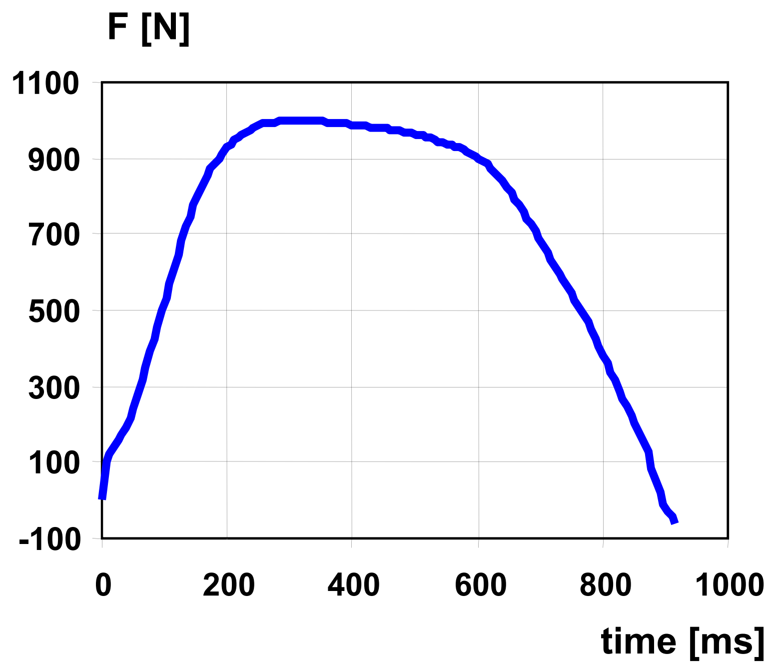
Biomechanical feedback in the racing boat

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

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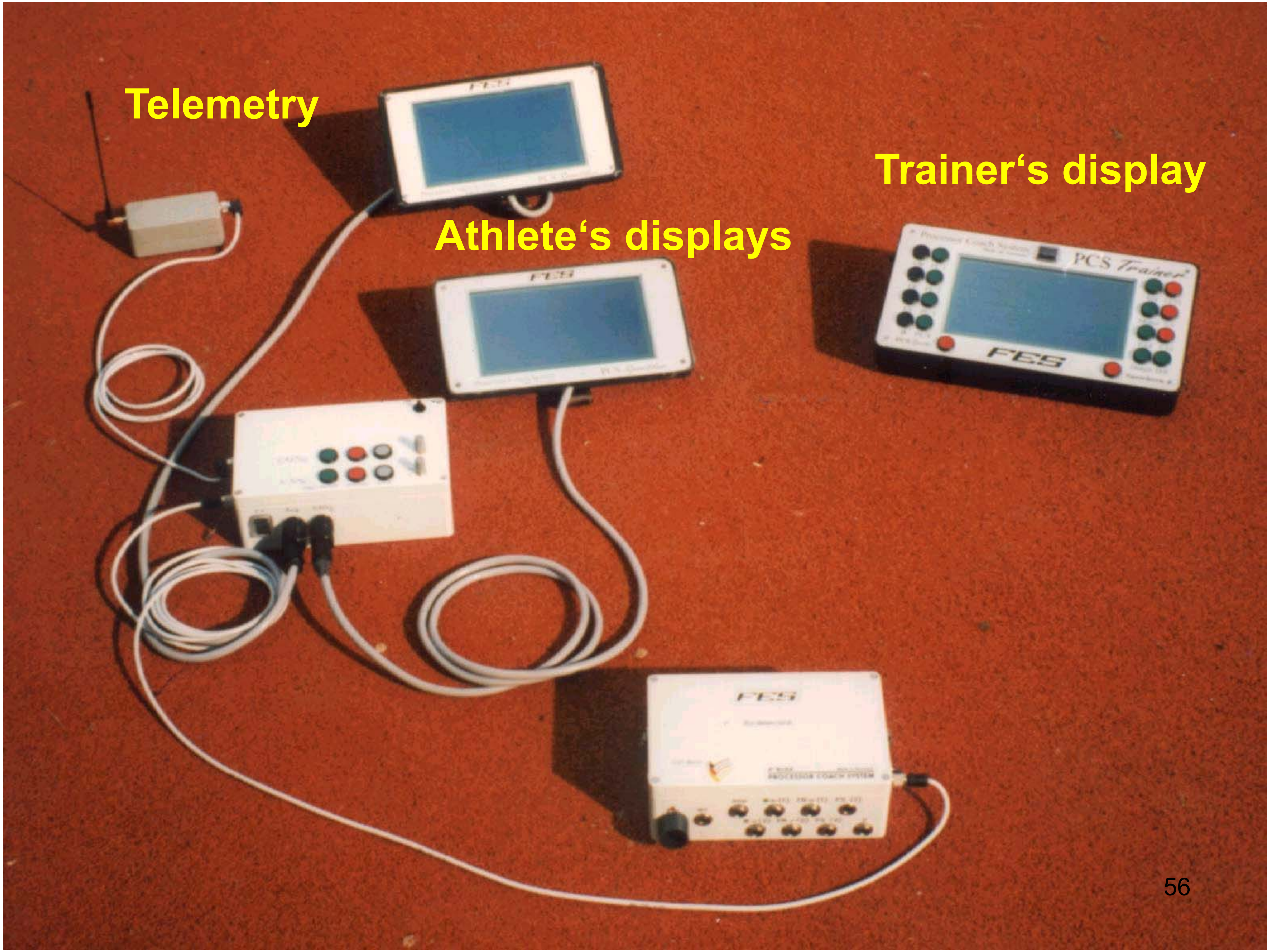
- Some mistakes in rowing technique are hard to eliminate (force structure).
- Kinaesthetic information is unconsciously.
- Force patterns are difficult to observe by the coach.
- Coach and athlete need more quantitative information with higher precision.



Telemetry
Trainer‘s display
Athlete‘s displays
PCS Trainer
FES

Feedback display

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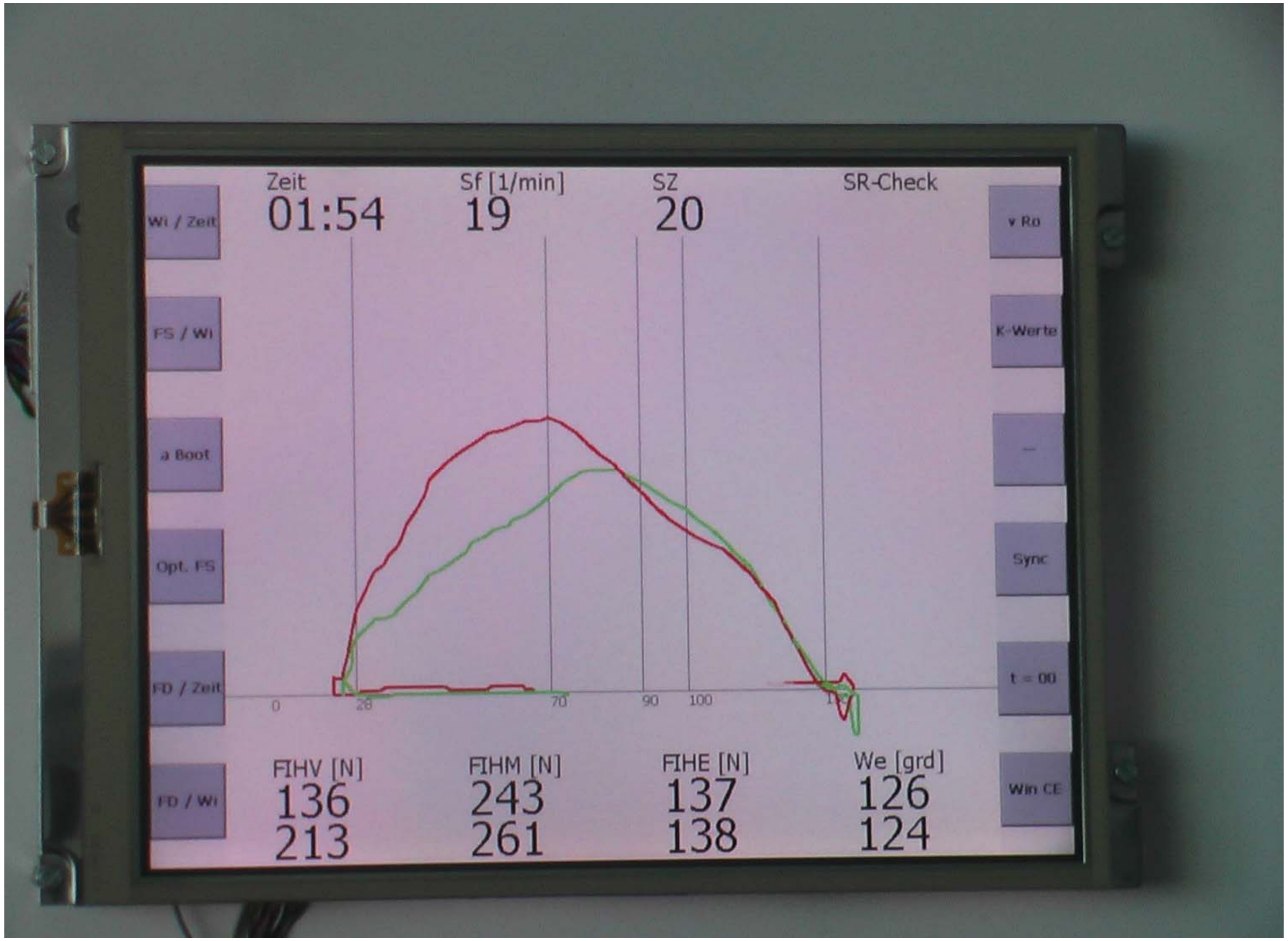

Feedback display

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Feedback training procedure

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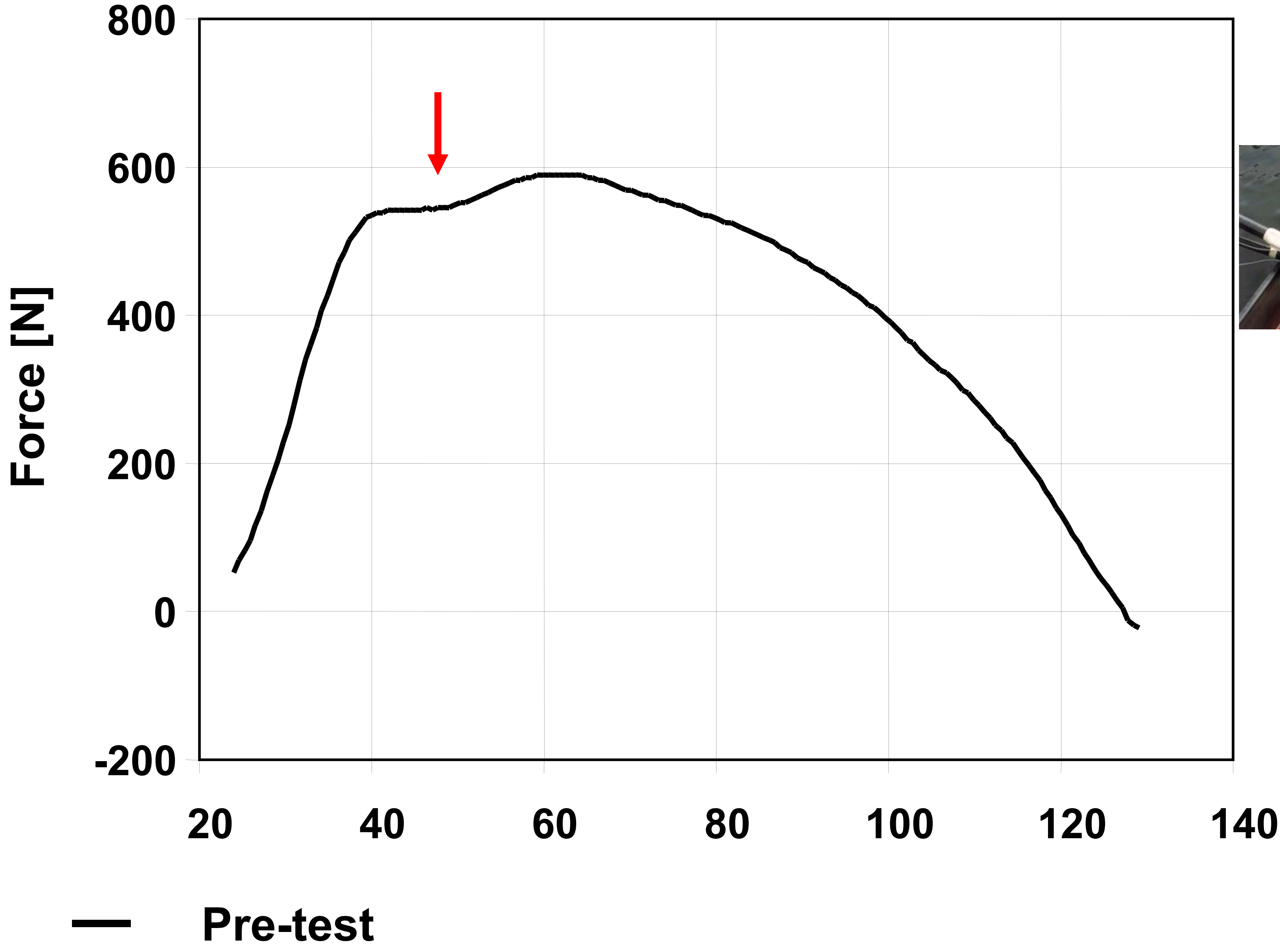
- Before feedback training: biomechanical analysis of technique to identify the objectives of feedback training
- In feedback training: the athletes are asked to vary the movement in order to change a technical feature. The athlete monitors and regulates the movement with the help of objective feedback
- 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]



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

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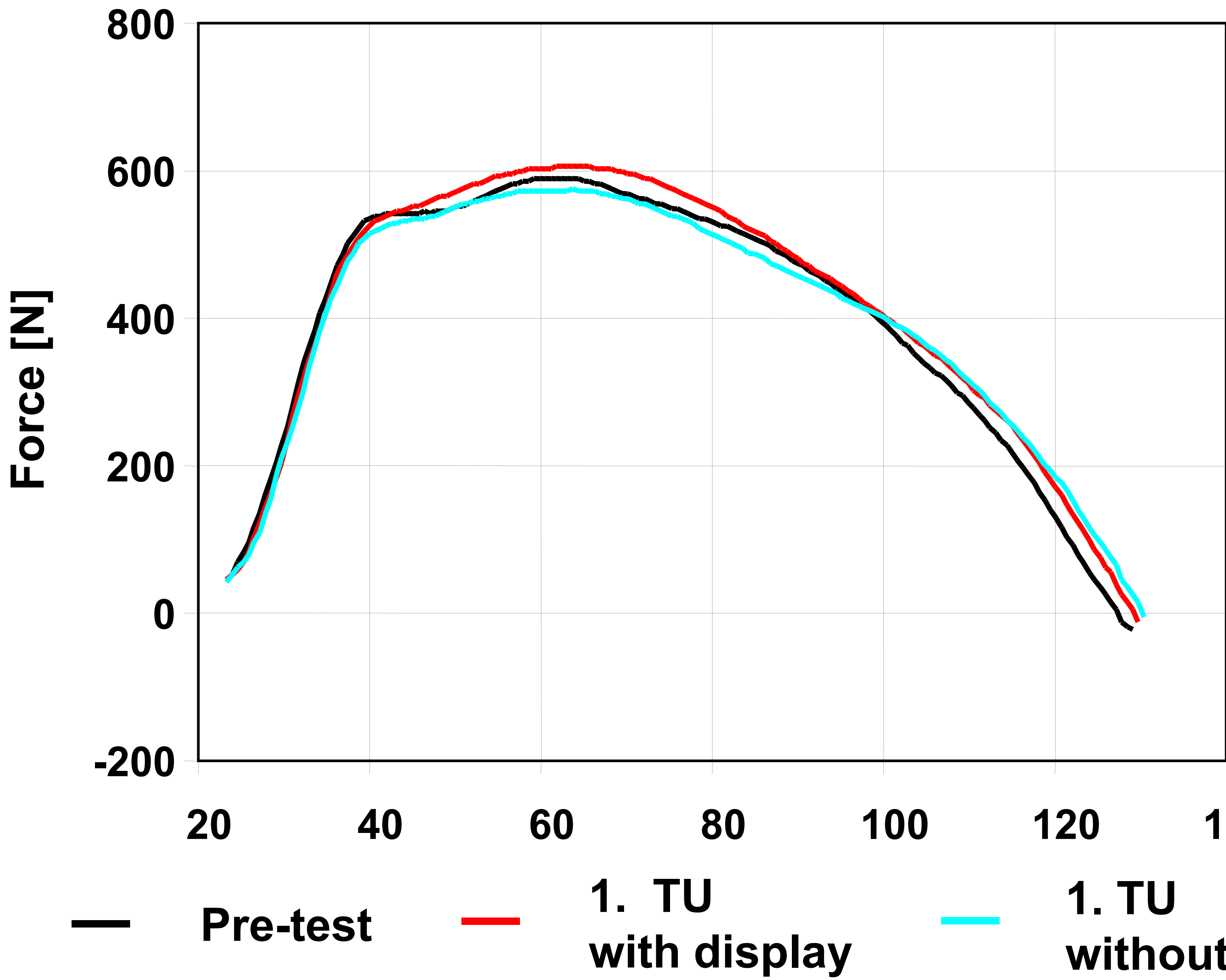
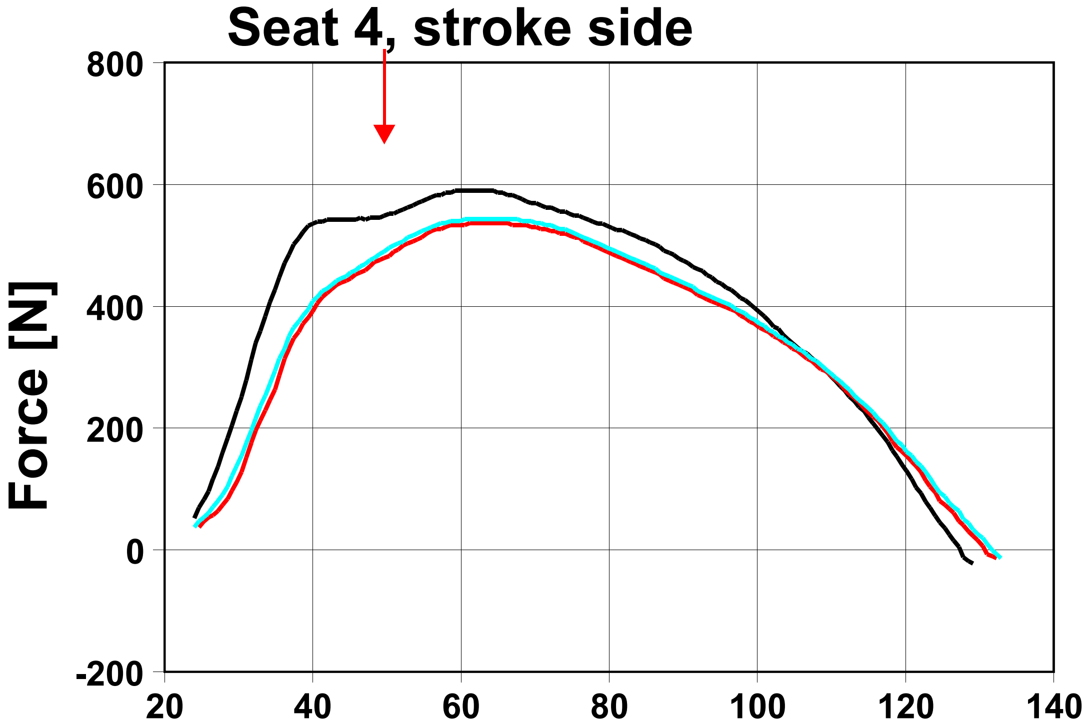
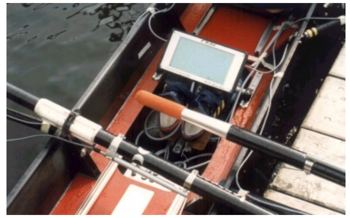
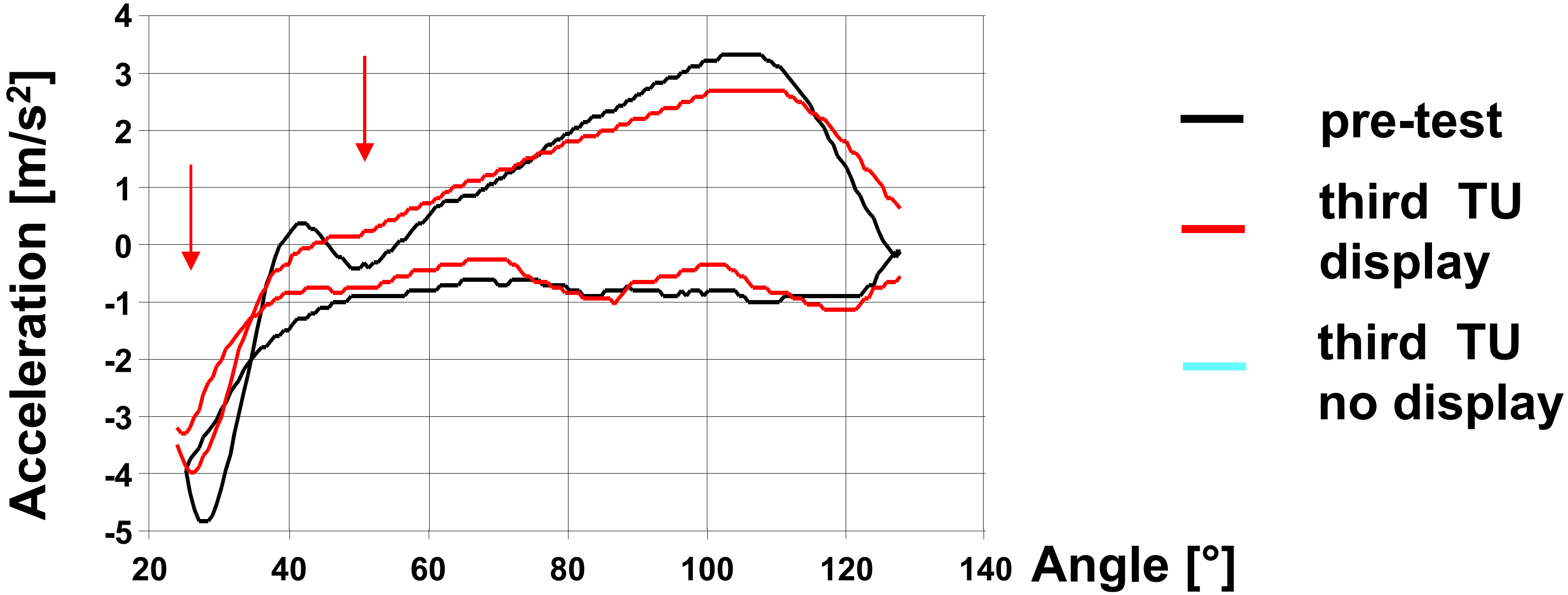


Comparison between pre-test and third training unit (TU), 4x, SR 20







Gate-force-angle curve for an athlete before, during as well as after feedback

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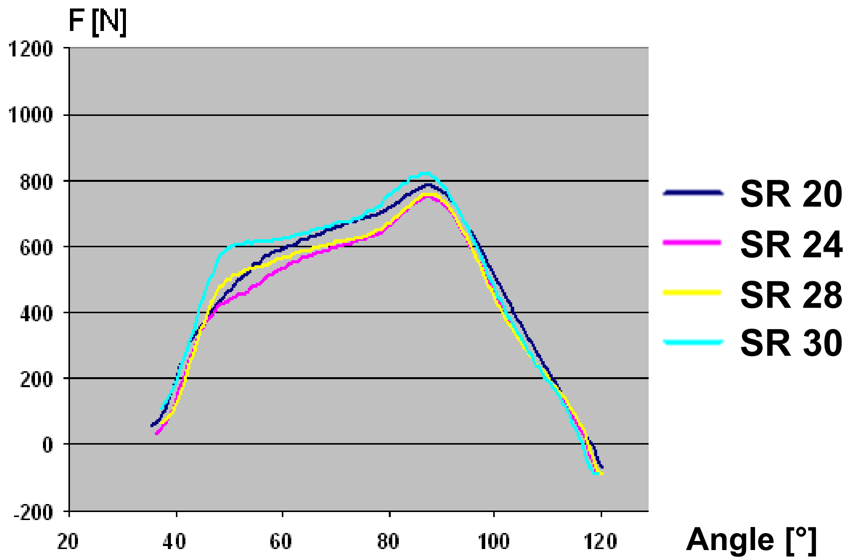
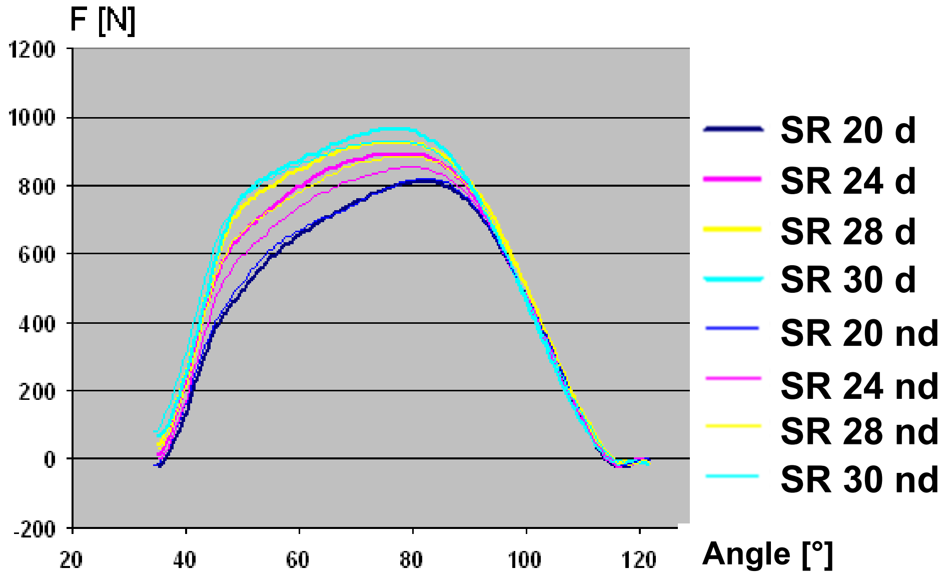
before feedback ⟶ **during and after feedback**





SR = stroke rate
d = with display
nd = no display

Comparison of the first test and deviation of intervention

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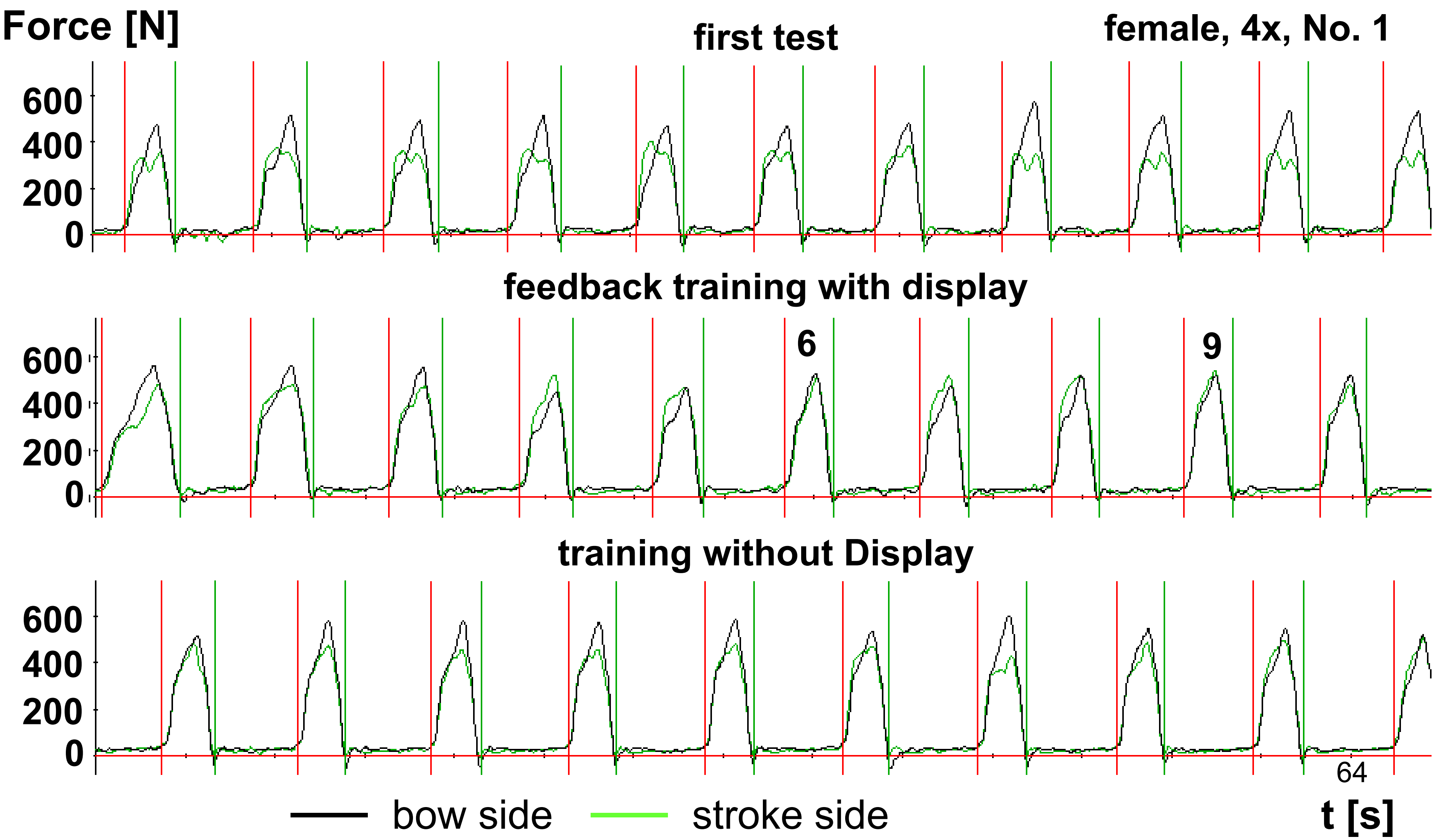

Approach using stroke length in big boats, N=4

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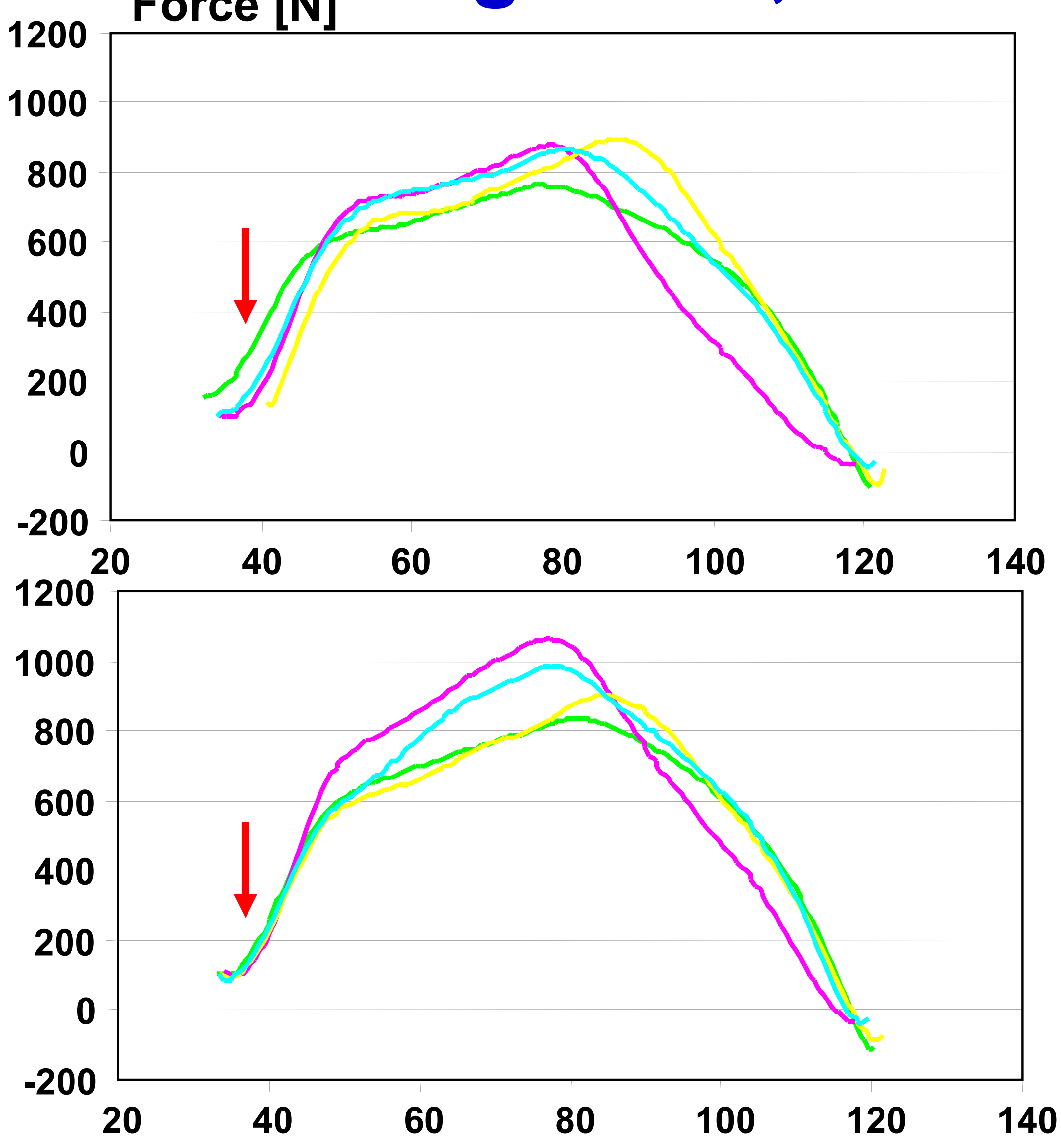

first test

SR=30 1/min

- No. 1
- No. 2
- No. 3
- No. 4

feedback training

SR=30 1/min

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

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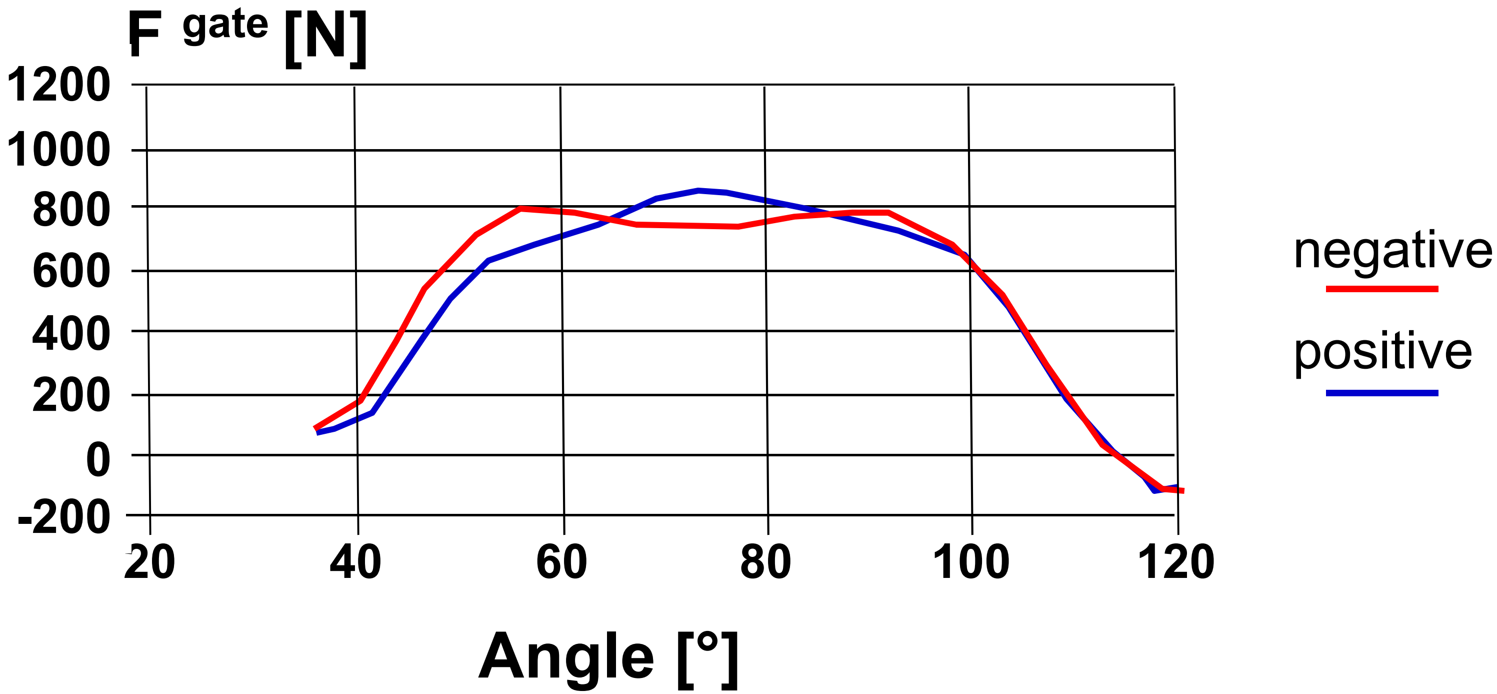
Positive and negative force curve characteristics for individual strokes



Feedback training

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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

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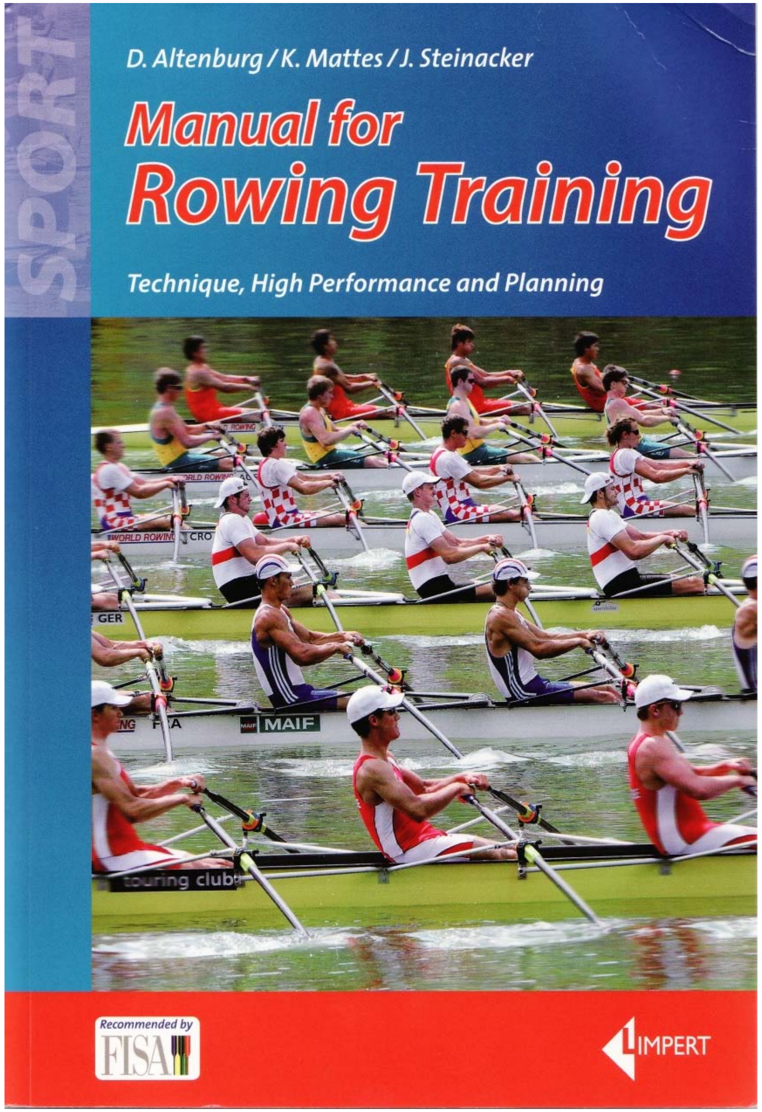

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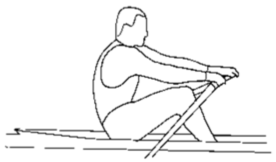
Diagnostic of rowing performance and technique to optimise the rowing technique

Prof. Dr. Klaus Mattes



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