Universität Hamburg
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UHH Bewegungs-& Trainingswissenschaft

How to interpret and Use Boat Biomechancis

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Structure

1. Sport technique and rowing technique
2. How is rowing performance and technique tested?
3. How can rowing performance and technique be interpreted?

Sports technique

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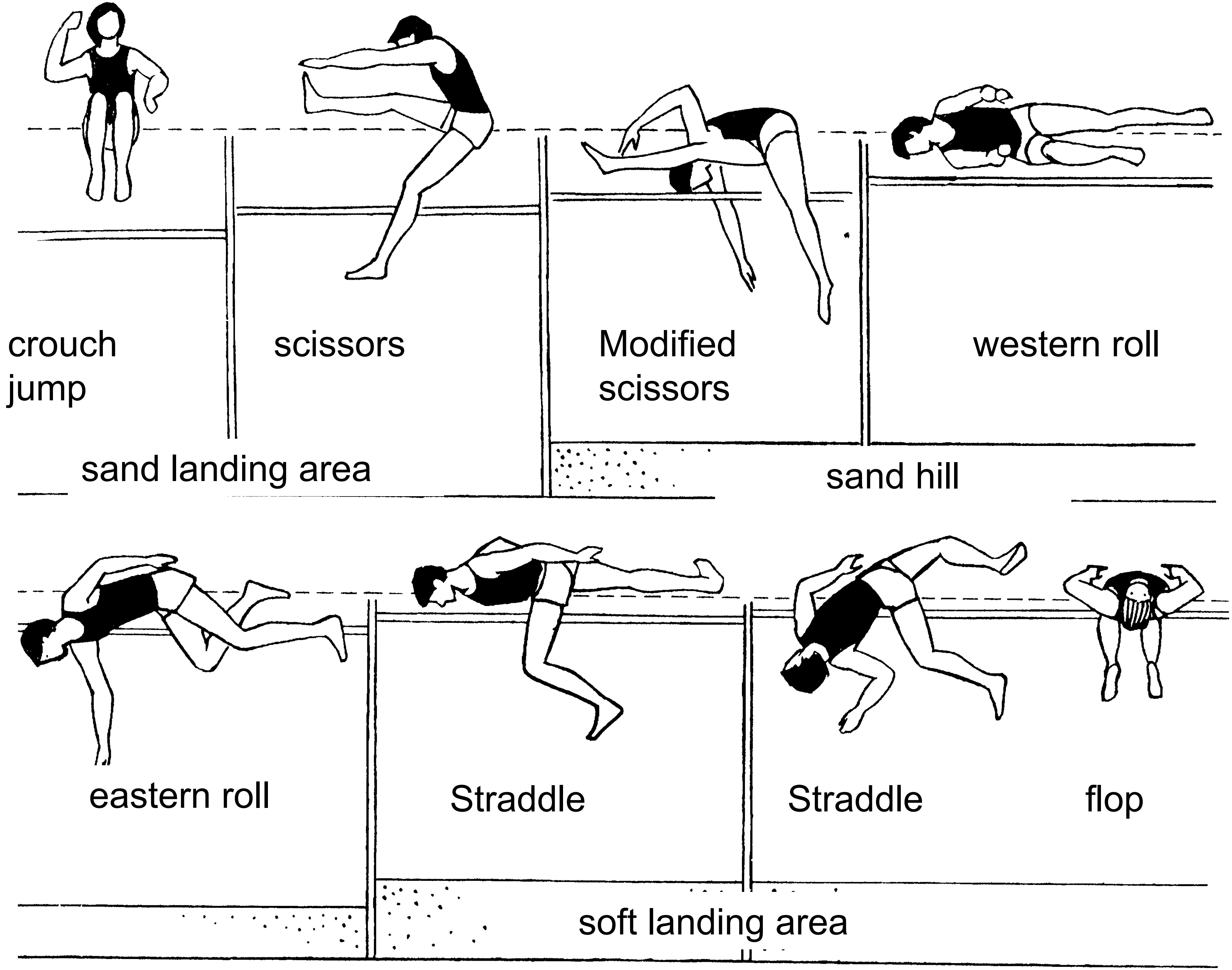
- Sports technique can be described as an effective solution for a specific movement task, tested and achievable in practice in terms of psycho-physical human attributes.

(Schnabel et al. 1977, 102; Martin et al. 1991, 45; Mechling et Carl 1992, 504)


crouch jump
scissors
Modified scissors
western roll
sand landing area
sand hill
eastern roll
Straddle
Straddle
flop
soft landing area

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

Structure

1. Sport technique and rowing technique
2. How is rowing performance and technique tested?
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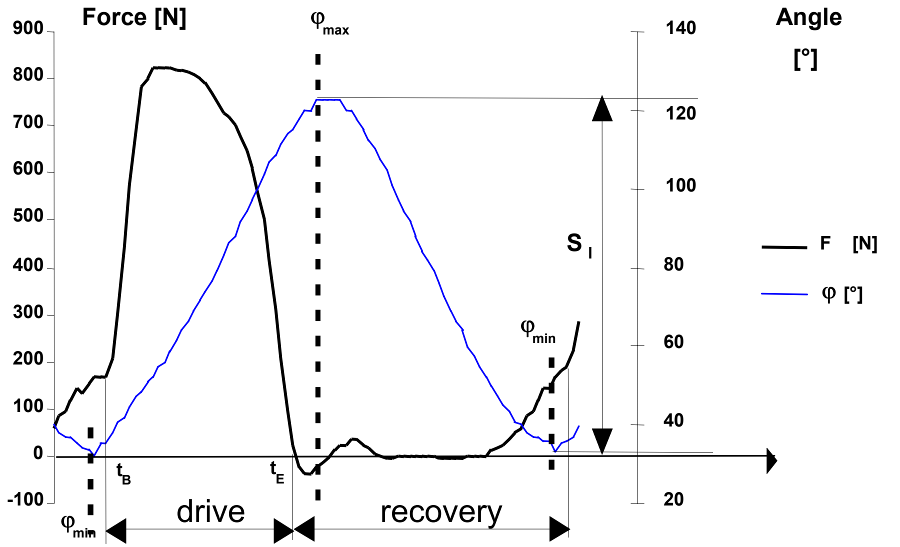
Rowing technique

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

characteristic curves



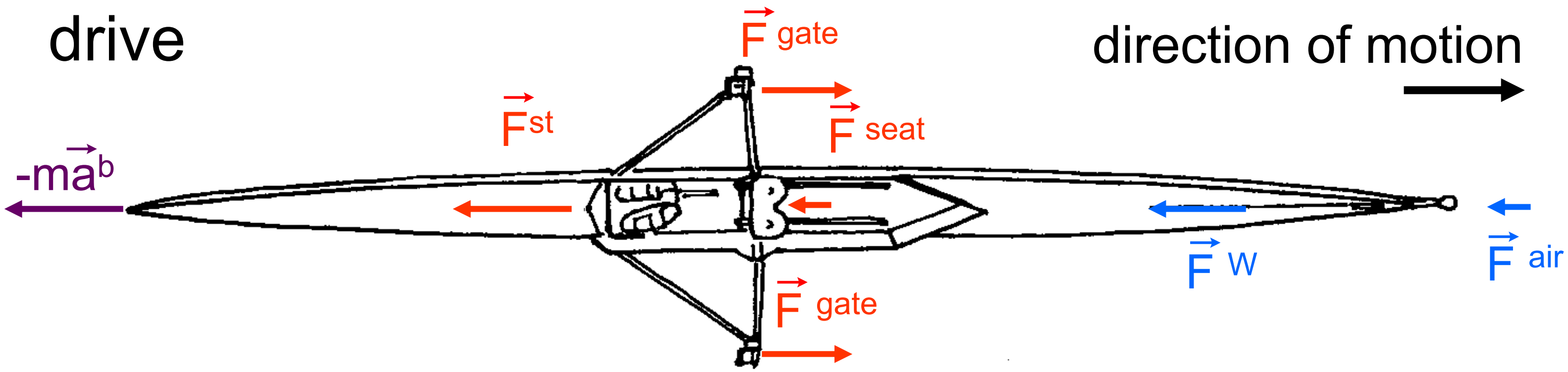
characteristic values

F_{max} = 810 N

F_{mean} = 600 N

t_{drive} = 0.72 s

Applied forces on a boat



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

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

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

m = mass

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

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

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

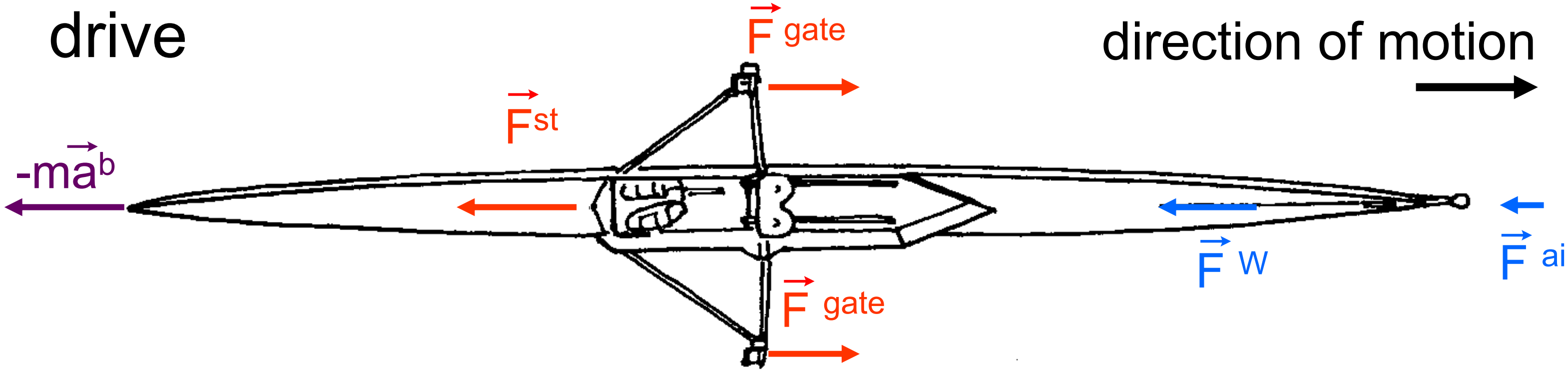
$\vec{F}^{\,seat}$ = seat force

$\vec{F}^{\,st}$ = 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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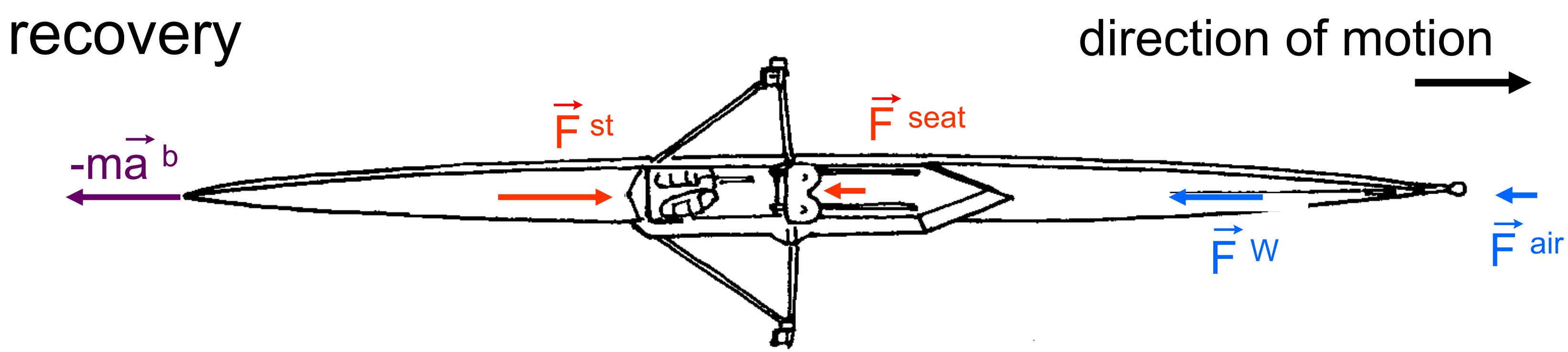
Applied forces on a boat



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

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

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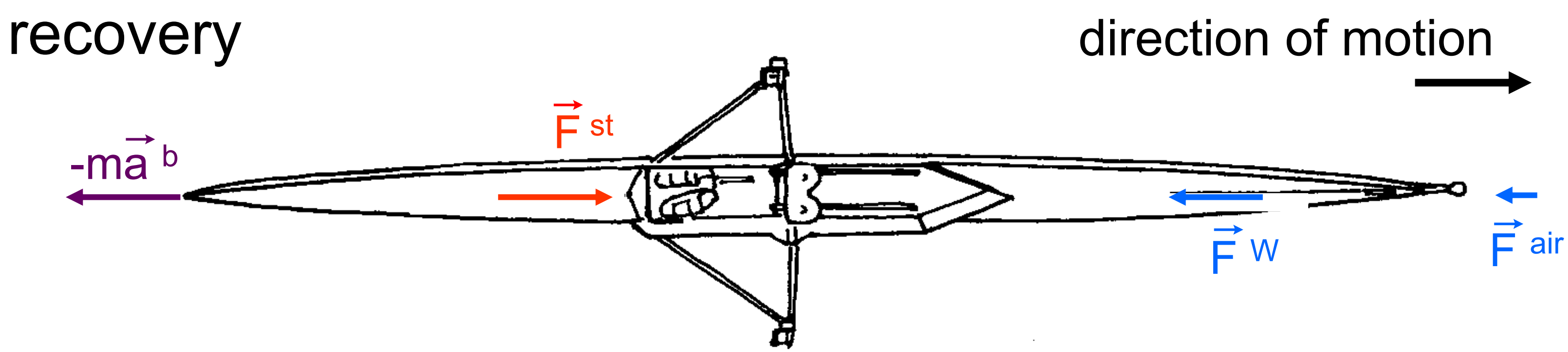
Applied forces on a boat



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

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

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

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Applied forces on a boat

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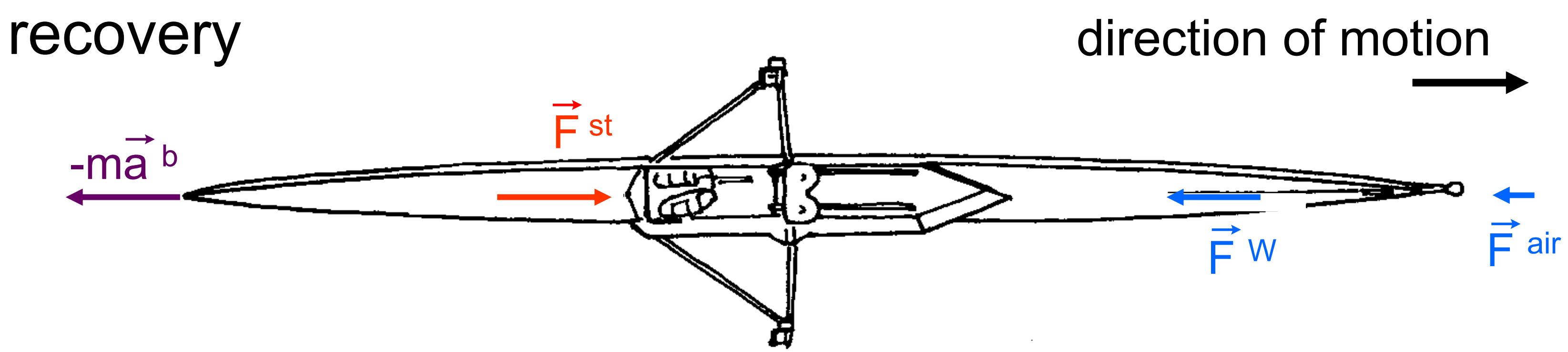

$$\vec{F}^{b} = \vec{F}^{st}$$

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

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

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$\vec{a}^{\,b}$ = 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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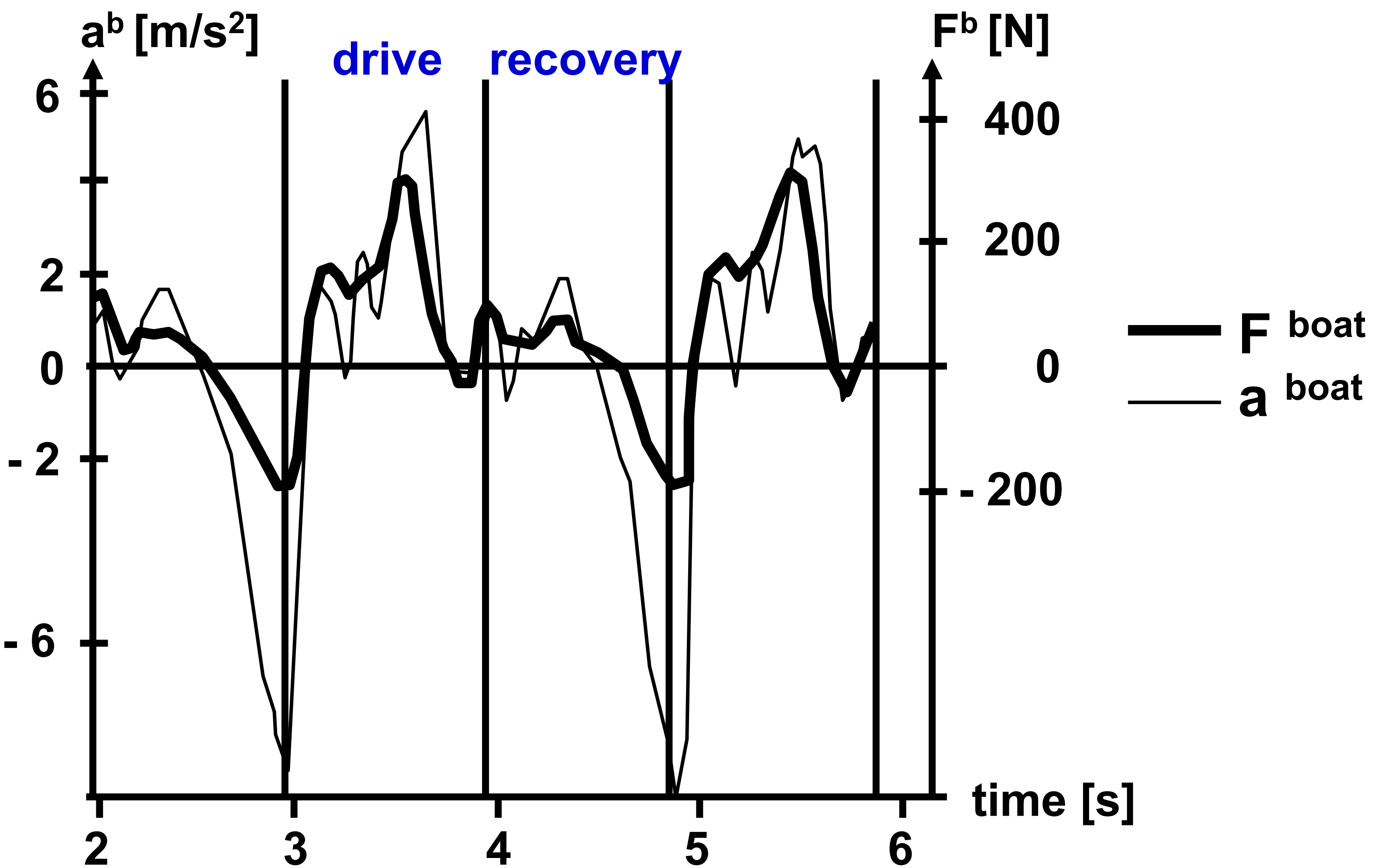
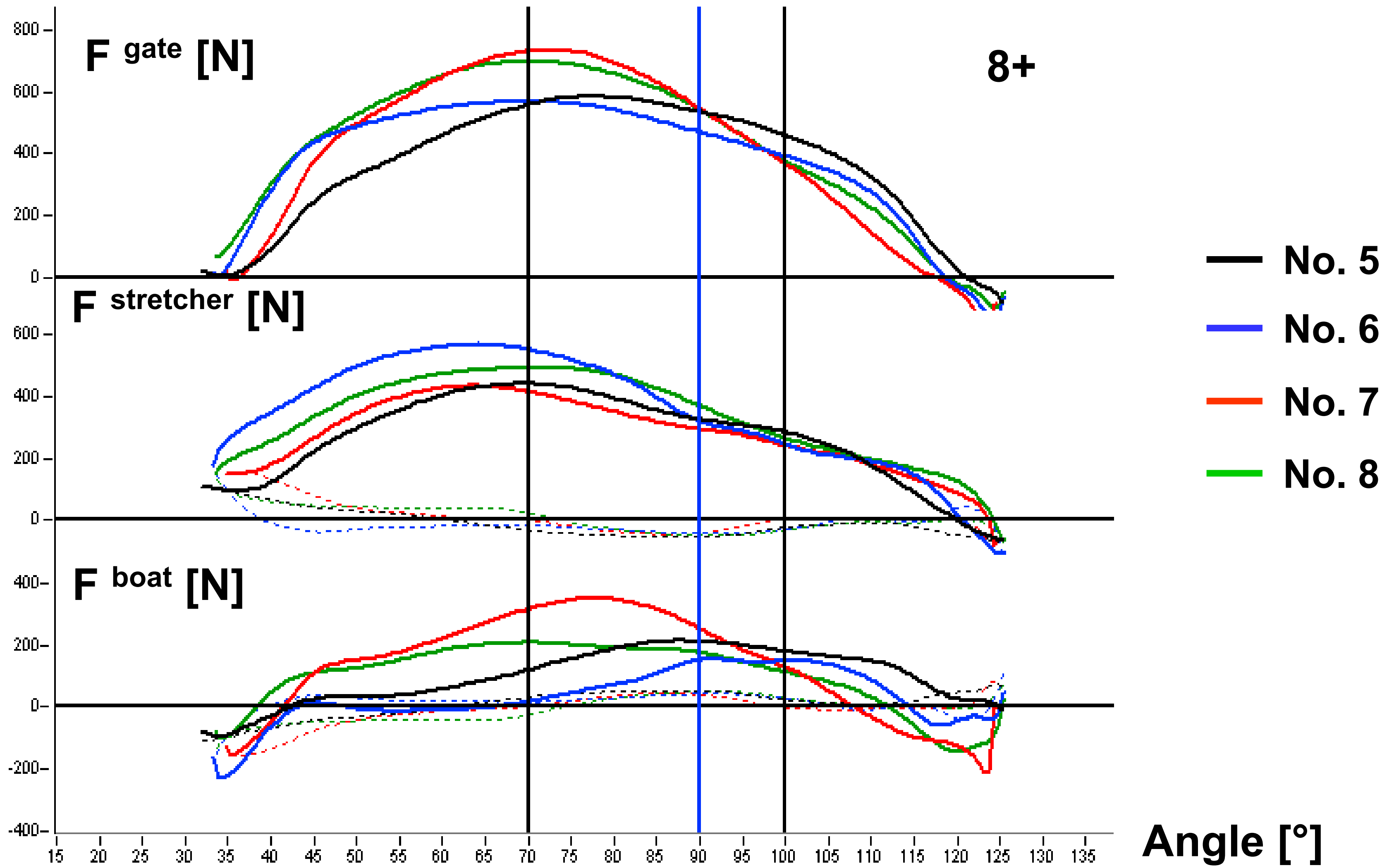


Force-angle curves, four rowers, same stroke rate



Force-angle curves, one rower, different stroke rates

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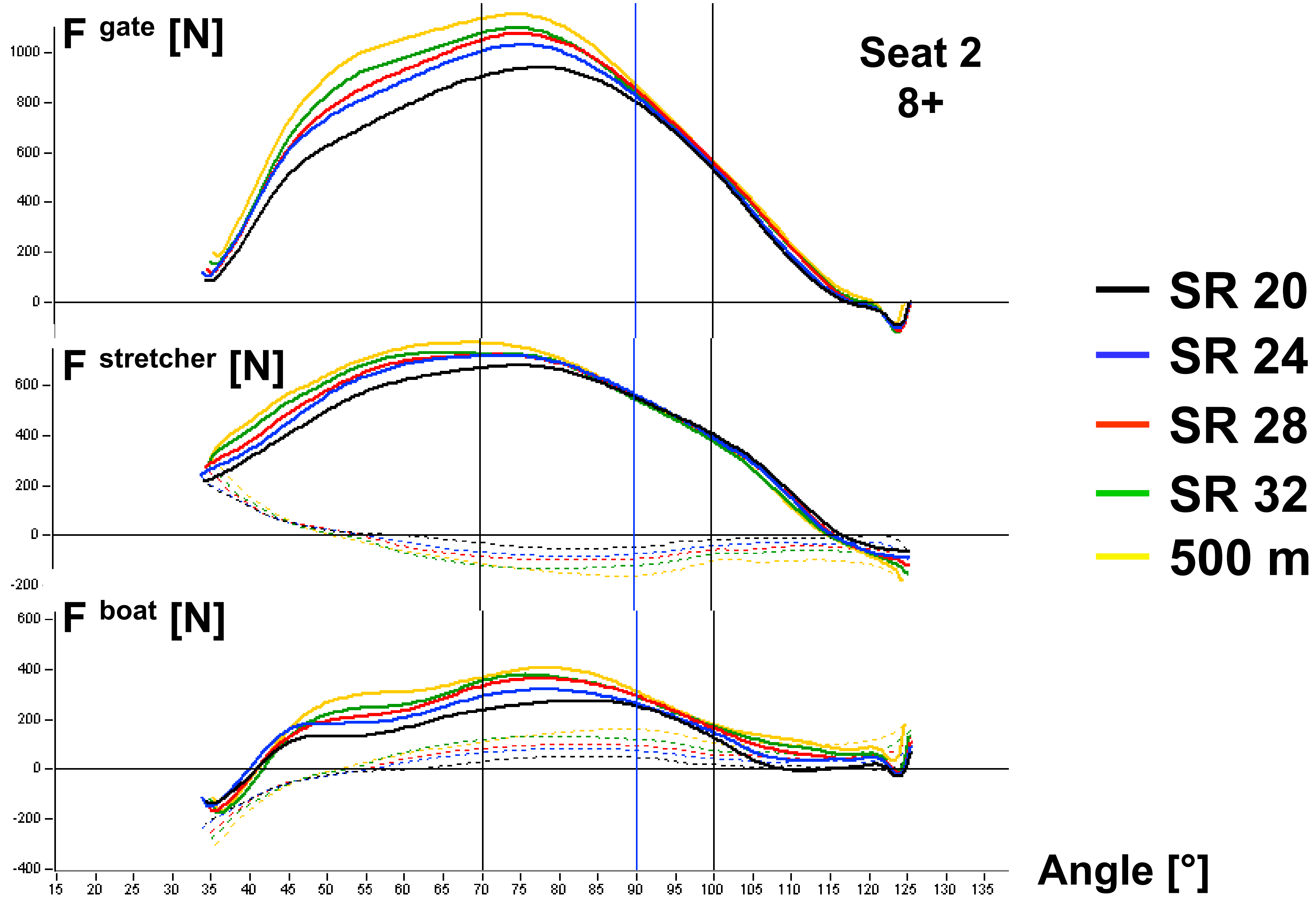
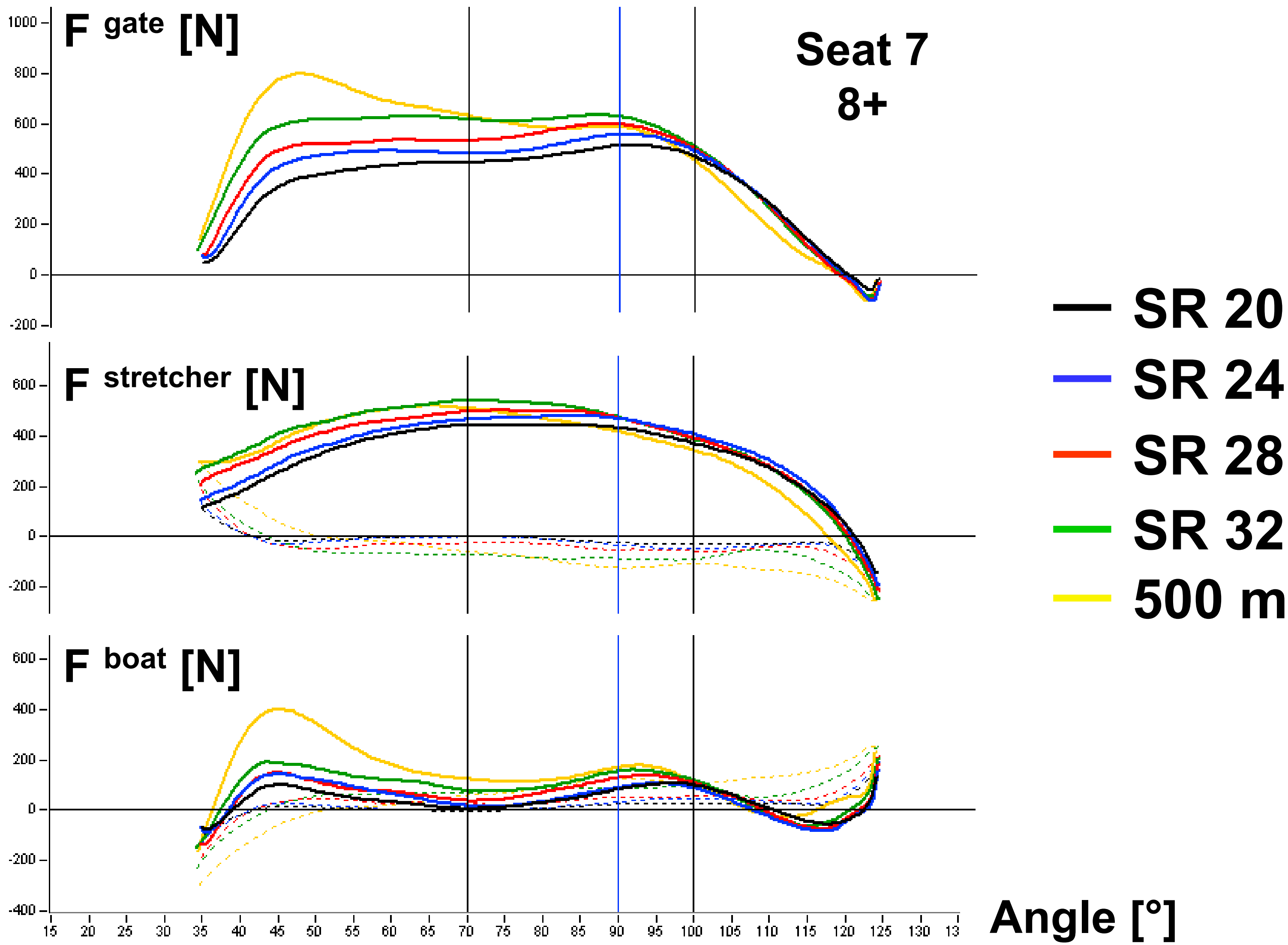


Force-angle curves, one rower, different stroke rates



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Synchronisation of video and biomechanical data

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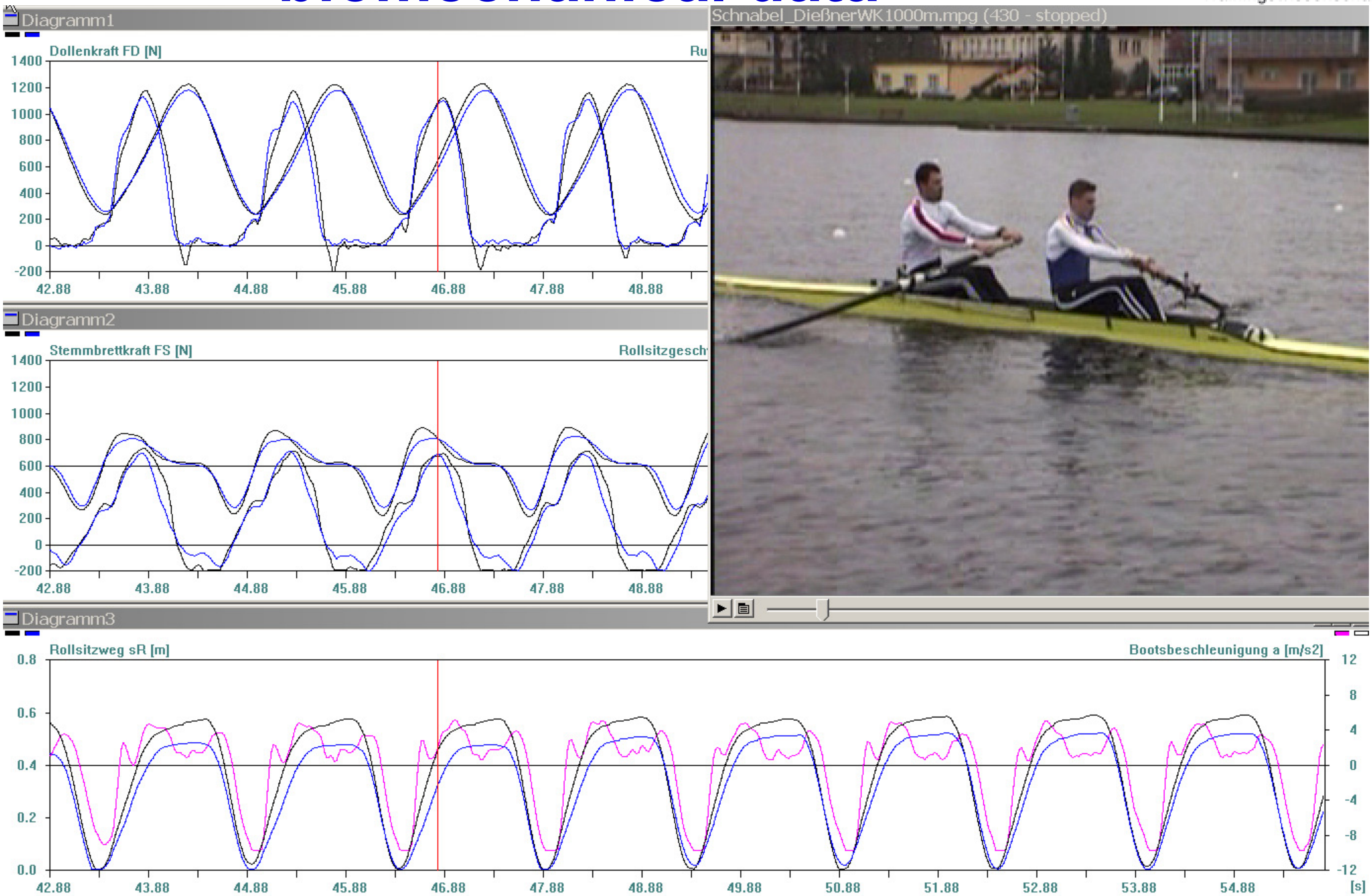

Important aspects of rowing technique

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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.

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})	

Structure of the rowing stroke

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finish (f) | recovery (r)

catch (c) | drive (d)

Structure

1. Sport technique and rowing technique
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Comparison of biomechanical curves for rowing technique

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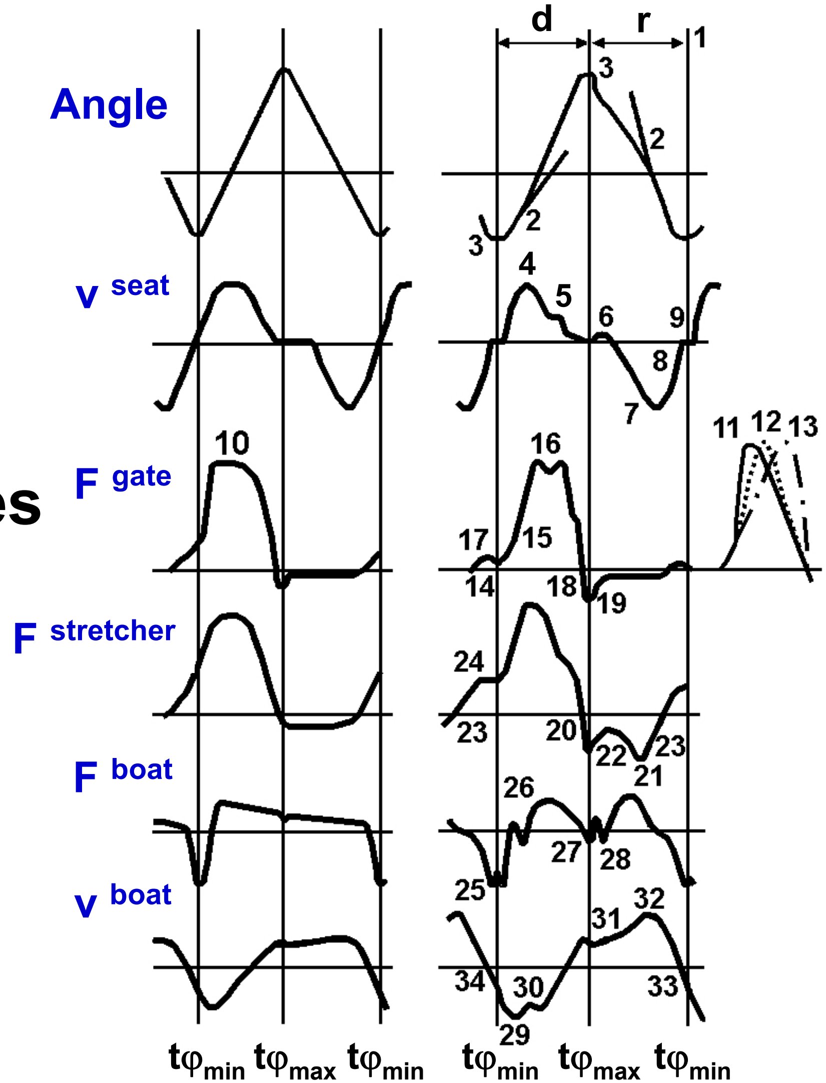
ideal curves

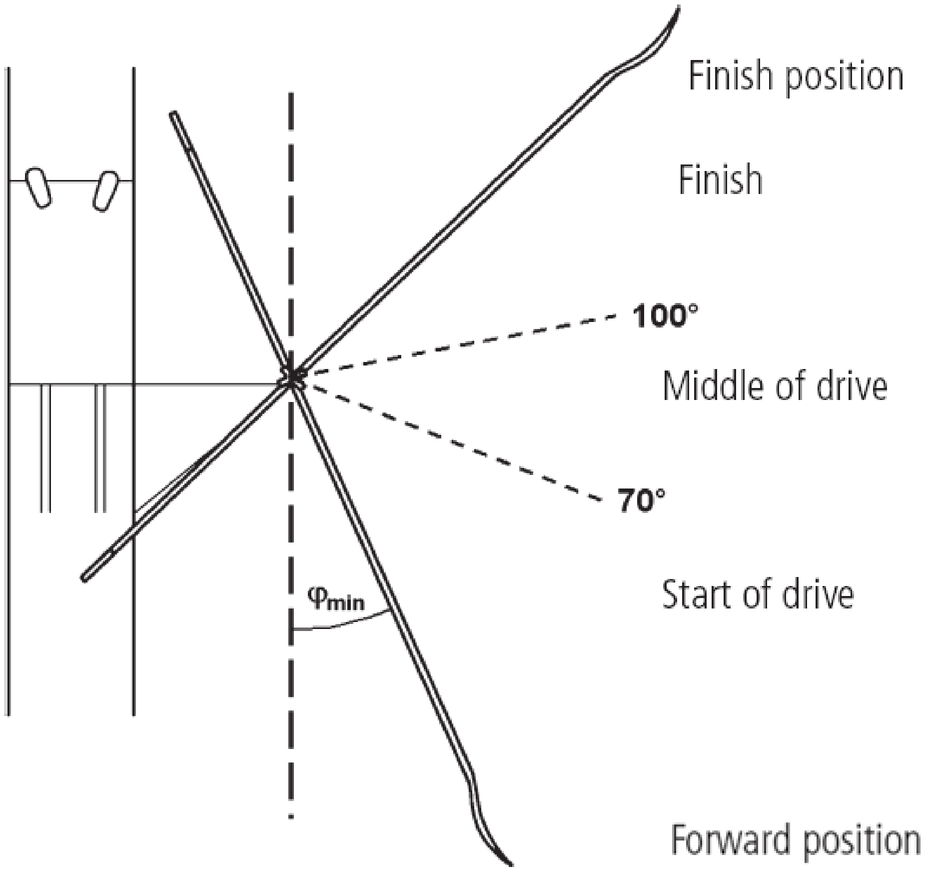


d = drive

r = recovery

curves with error illustrations

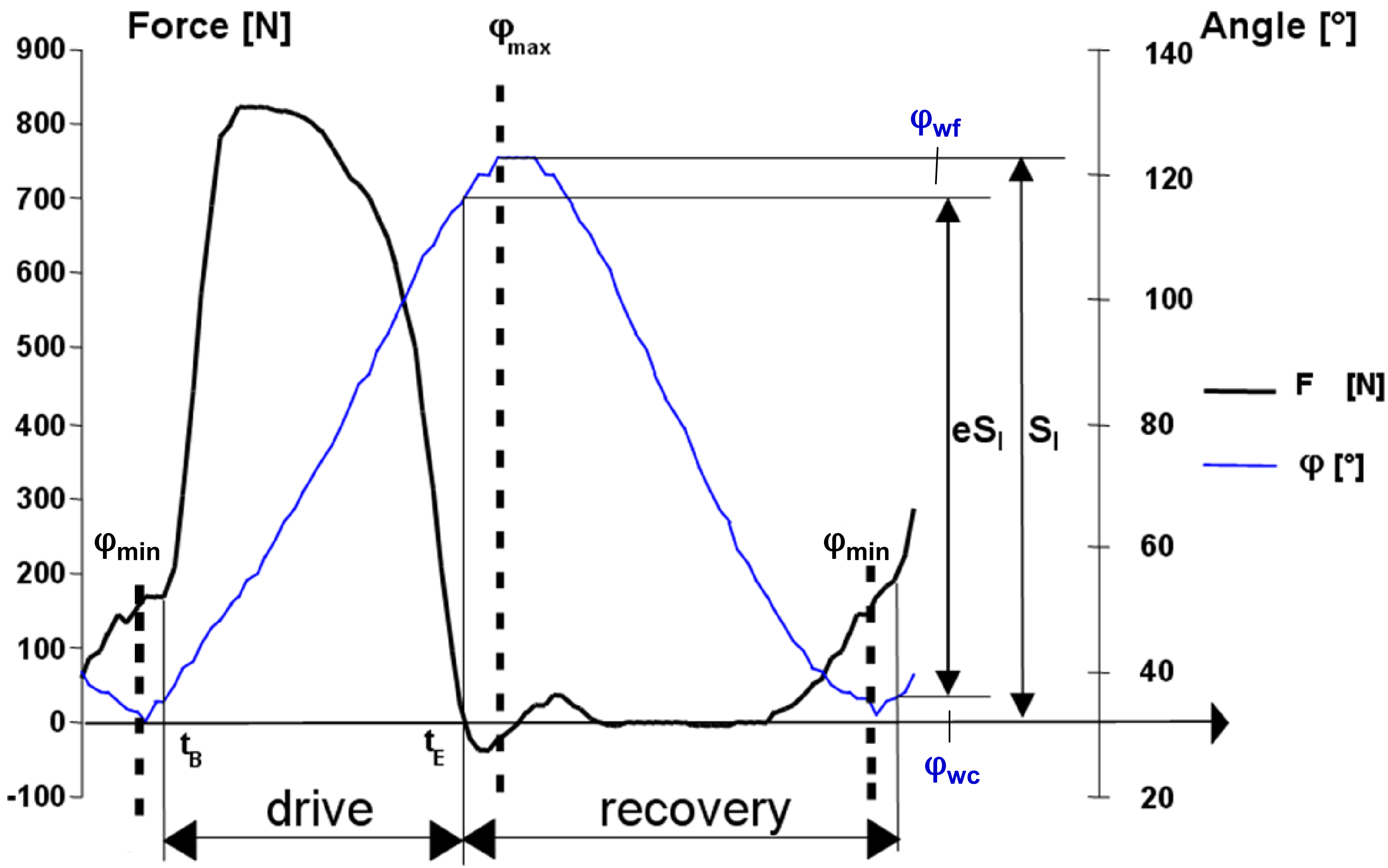
Rowing angle and stroke phases



φ_{min}= catch angle = 24-36°

φ_{max}= finsh angle = 126-136°

Rowing movement structure



Characteristic oar angle-time curves

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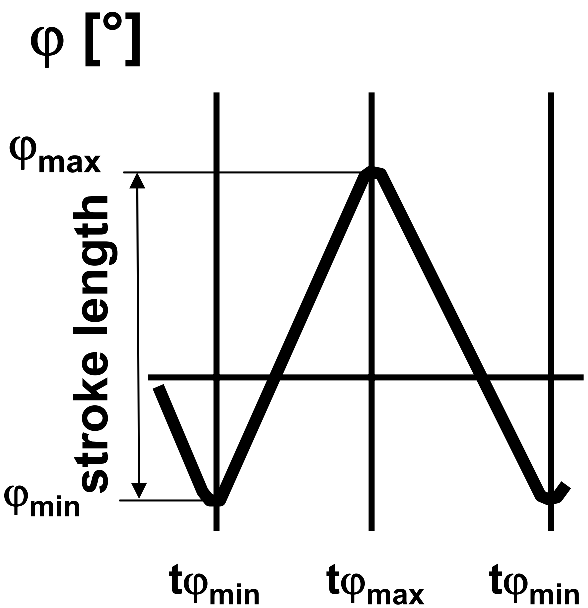
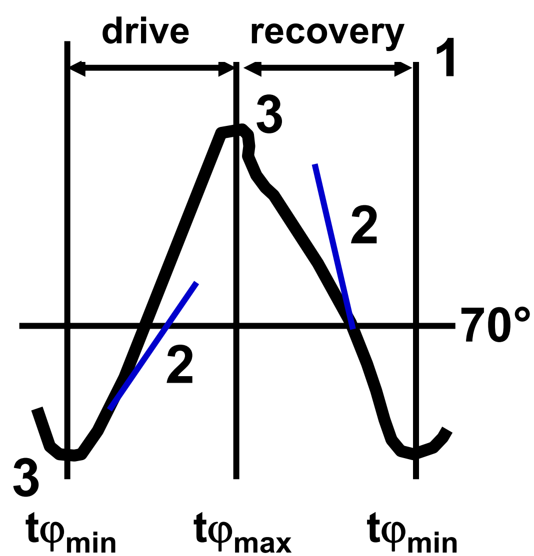
ideal curves



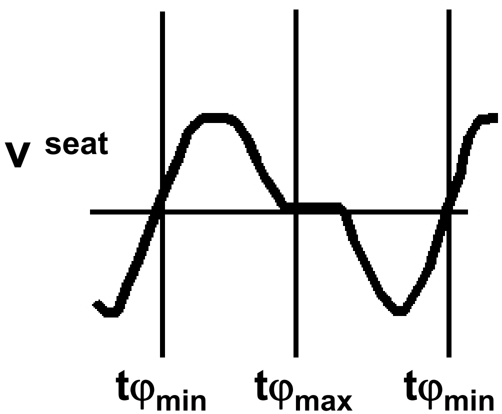
curves with error illustrations

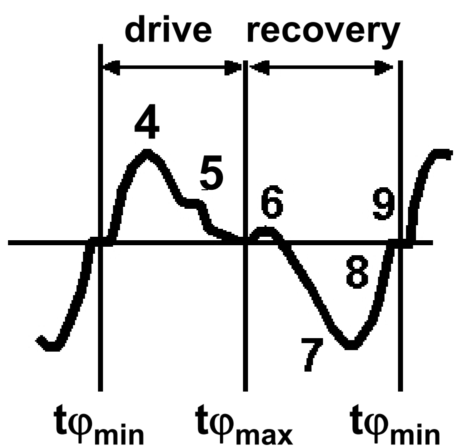


- rhythm ratio (1)
- steep or shallow rises mean high or low oar angular velocity (2)
- plateau indicates a stopping of the oar handle (movement pause) (3)

Characteristic seat-velocity time curves

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

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Stroke length, stroke angles and seat position

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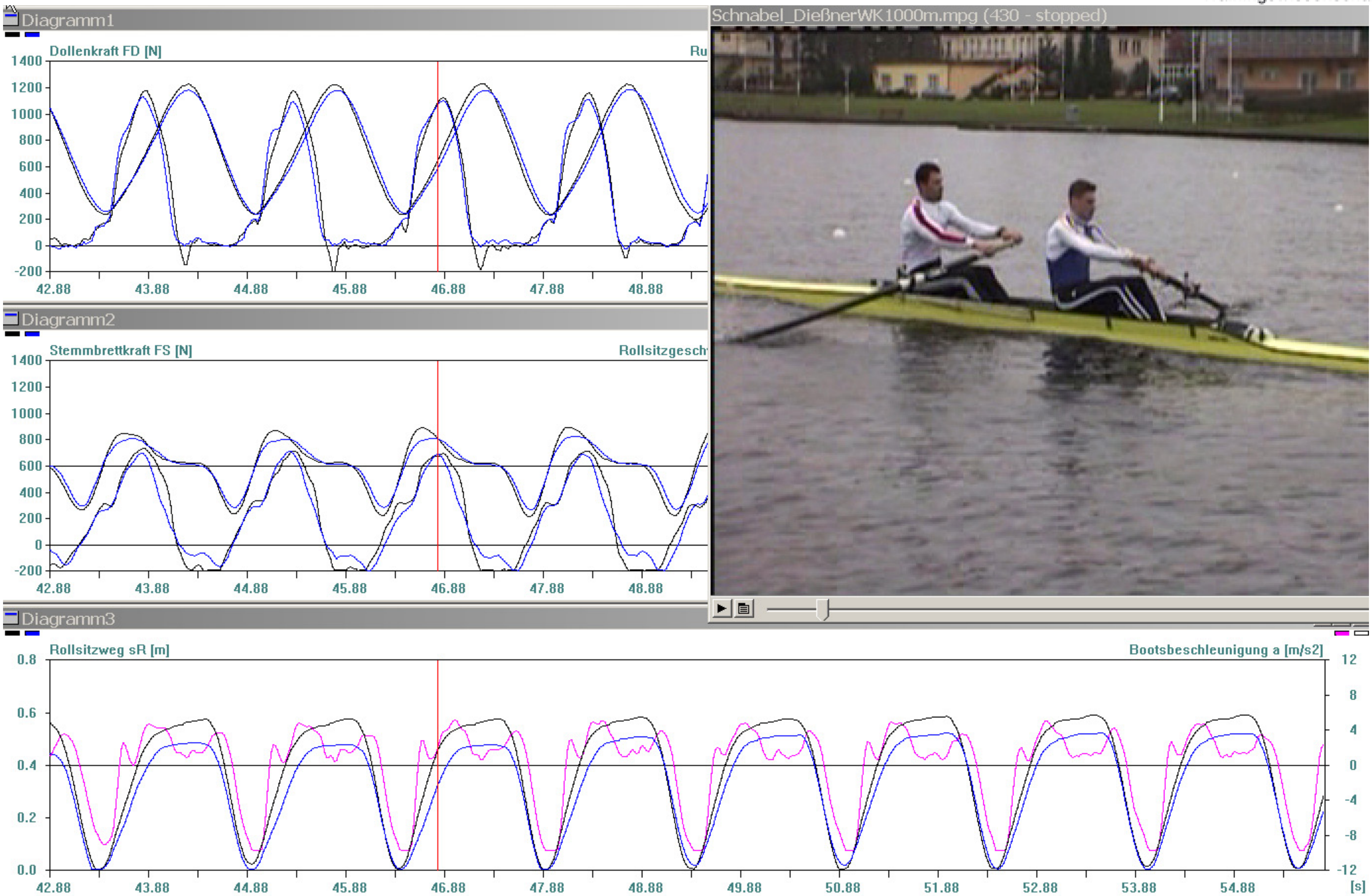
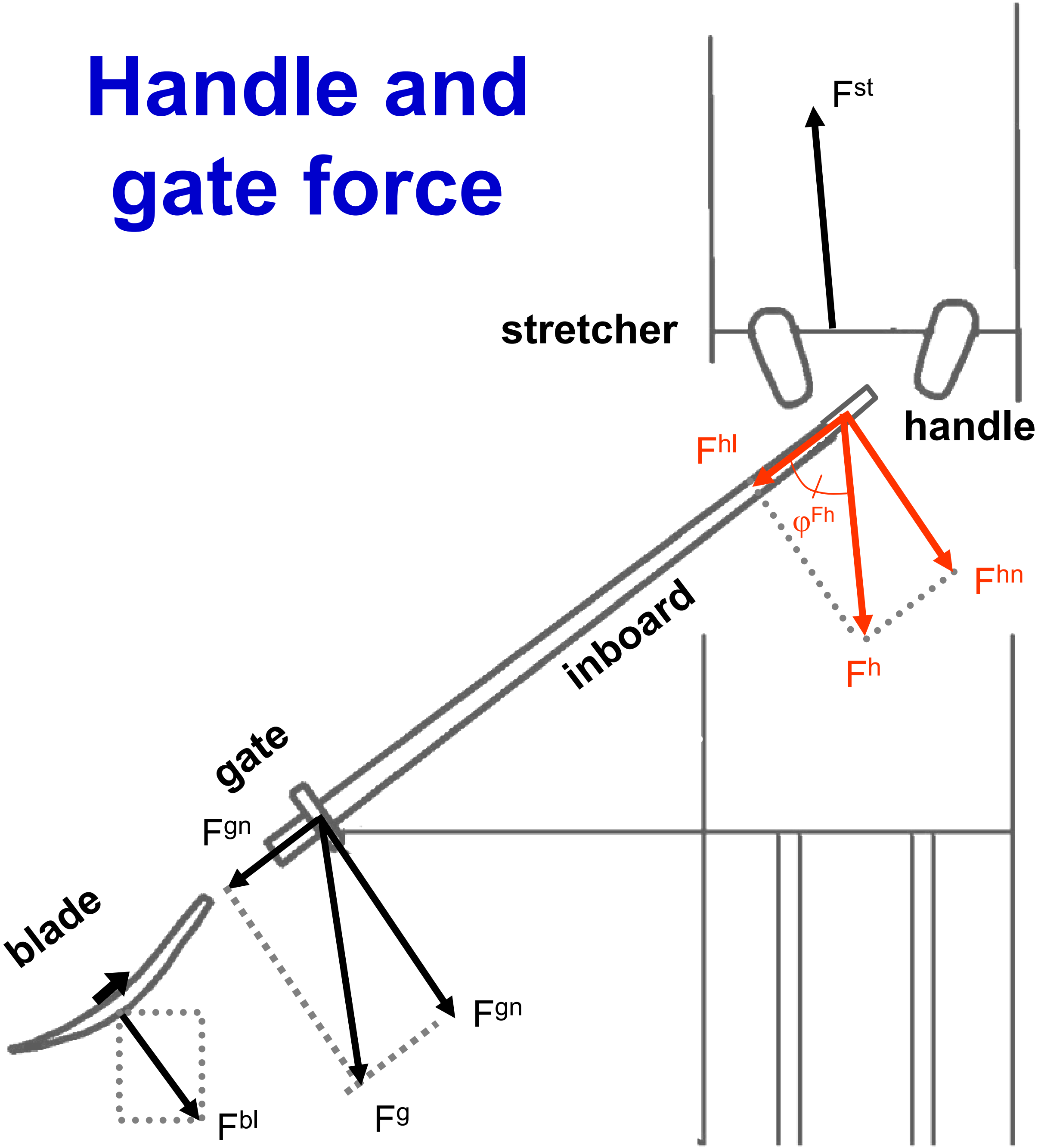
Senior women average values over 2000m

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



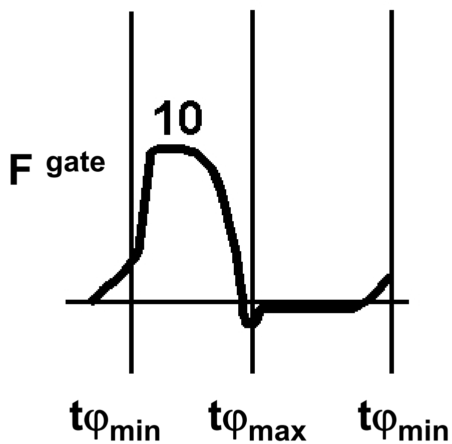
Handle and gate force

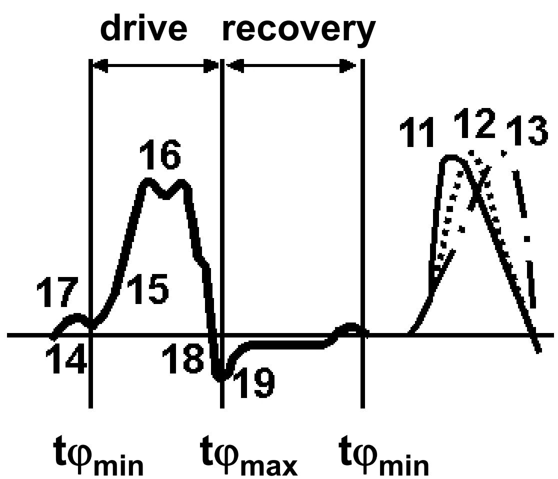


F^h	handle-force
F^{hn}	normal component
F^{hl}	longwise component
F^g	gate-force
F^{gn}	normal component
F^{gl}	longwise component
F^{bl}	blade-force
F^{st}	stretcher-force
φ^{Fh}	angle of pull direction

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

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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

Senior women 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
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

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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

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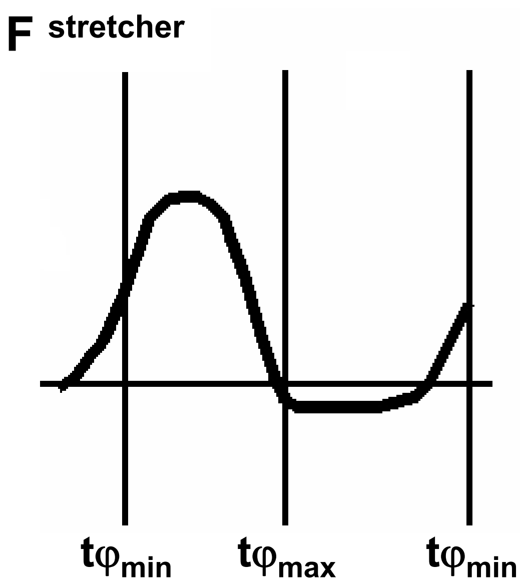
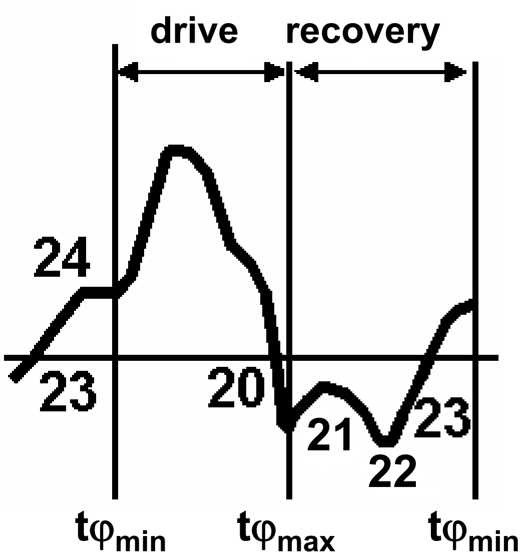
ideal curves



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

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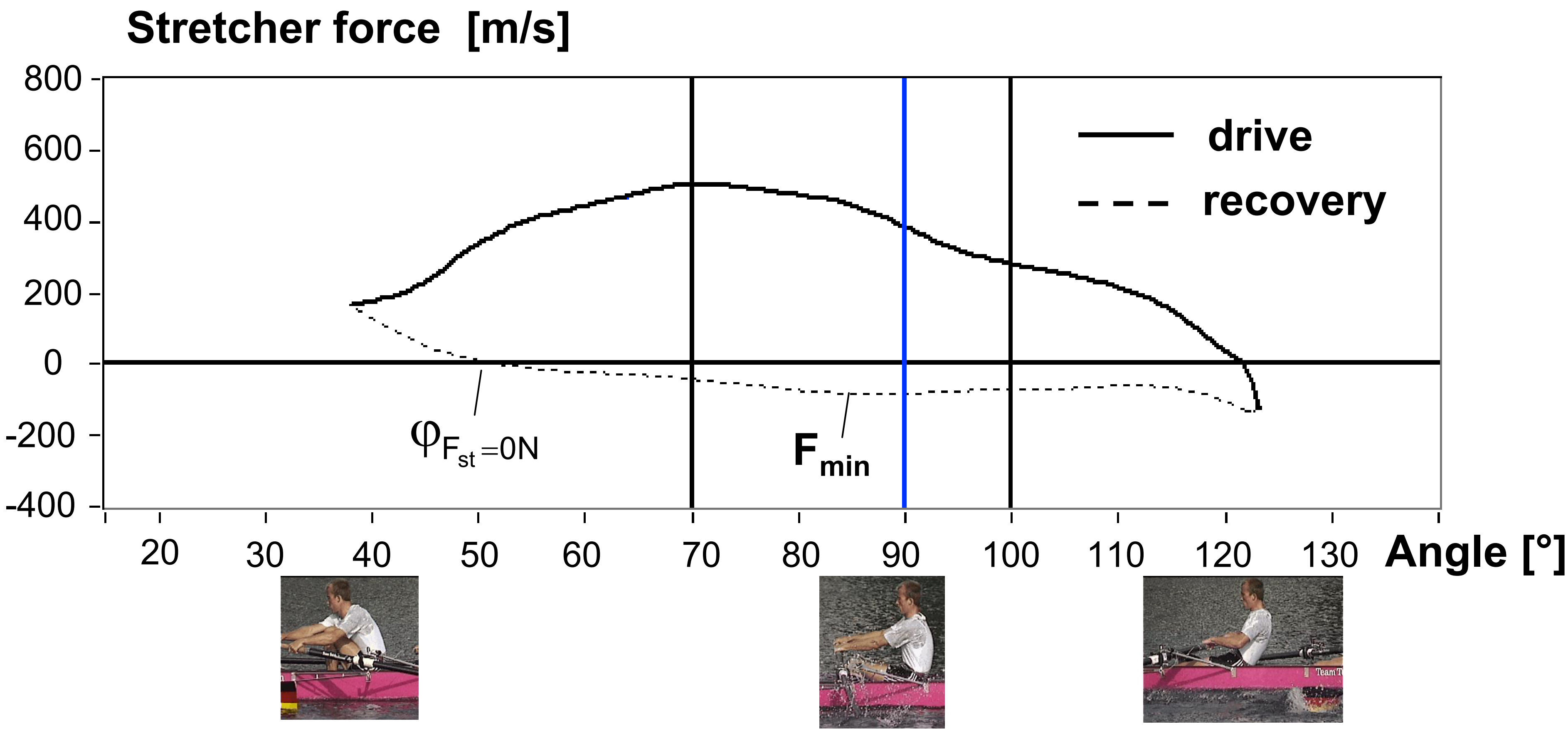

Evaluation of the recovery phase through stretcher force and seat velocity values

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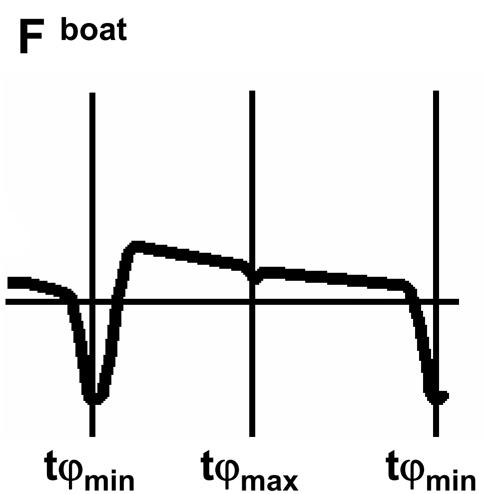
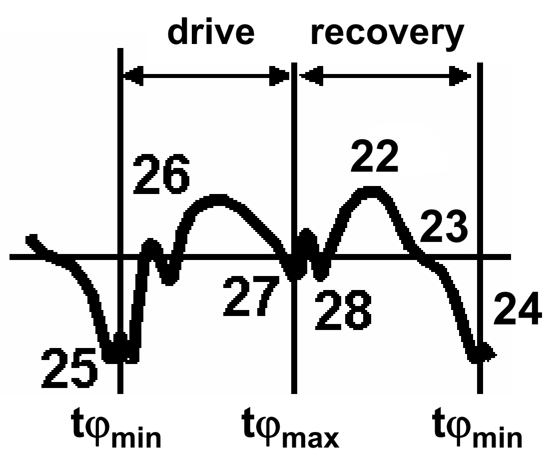
Characteristics of the recovery phase		
direct effect	• minimum of the stretcher force in the recovery [N] • oar angle to the point of zero stretcher force (Chance the stretcher force of pull to pressure force in the recovery) [°] • average seat velocity in the recovery [m/s]	$v_{min}^{stretcher}$ $\varphi_{F_{st}=0N}$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

Characteristic boat force-time curves

ideal curves **curves with error illustrations**

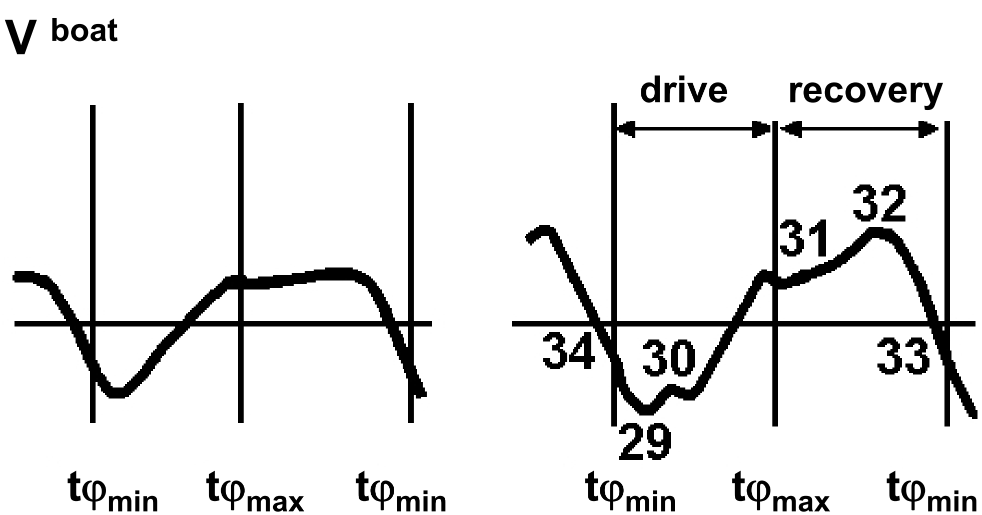




- discontinuities front reversal (25)
- late or interrupted development of boat-force in the start of drive (26)
- negative boat force at the finish (27)
- negative boat force in the back reversal (28)
- starting the sliding too harshly (22)
- change on the stretcher from pulling to pressure force (23)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

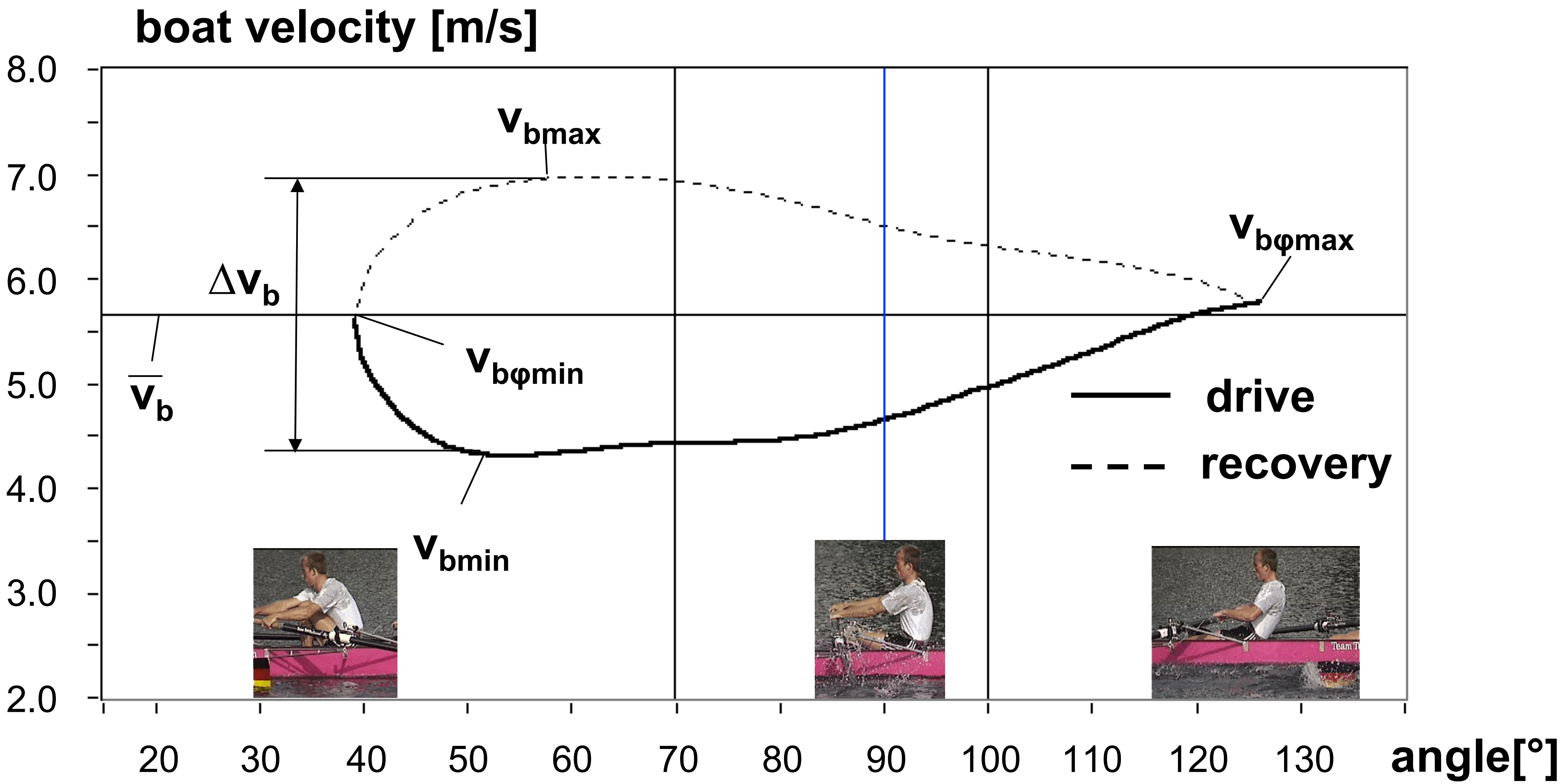
Characteristic boat speed-time curves

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})



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

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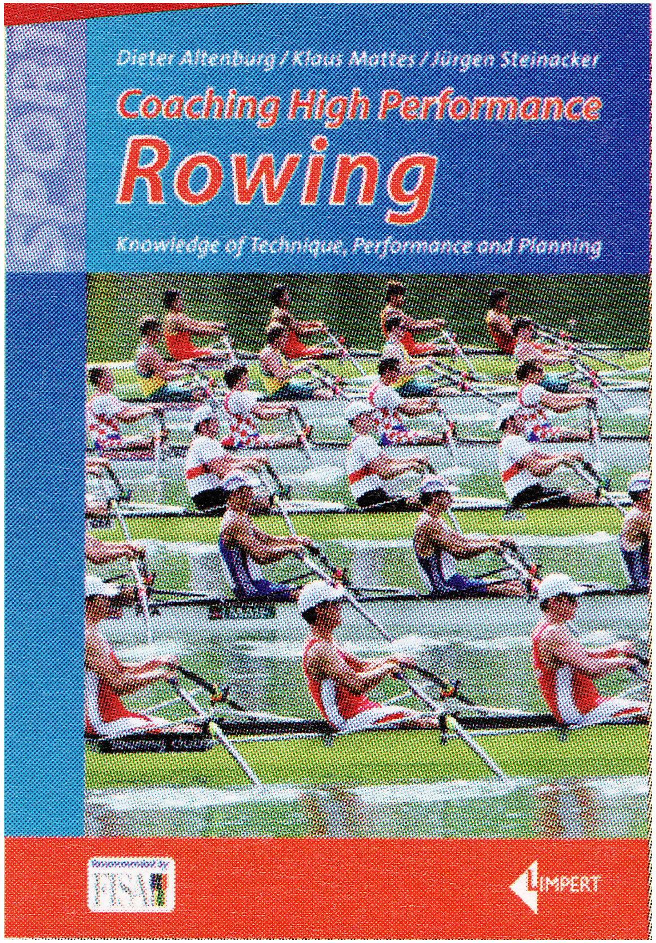
- Identification of a divergence by comparison with an ideal pattern
- During which oar-angle sector does the deviation appear?
- Which peculiarities do the other characteristic curves in the corresponding rowing phase exist?
- What effect is this having on the main aim (boat speed)?
- Which faulty movement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

For more information



Altenburg D, Mattes K & Steinacker J

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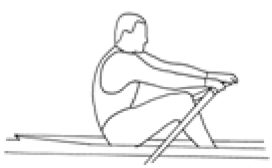
How to interpret and Use Boat Biomechancis

Prof. Dr. Klaus Mattes



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