Physiology of rowing

From laboratory to field

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Retrospective study of 15 years of collaboration with French federation, coaches and rowers

From 1993 to 2006:

- 452 tests
- 144 male and 55 female rowers

(from national to international level)

- 79 male and 20 female rowers came at least twice
- 1 rower was tested 14 times

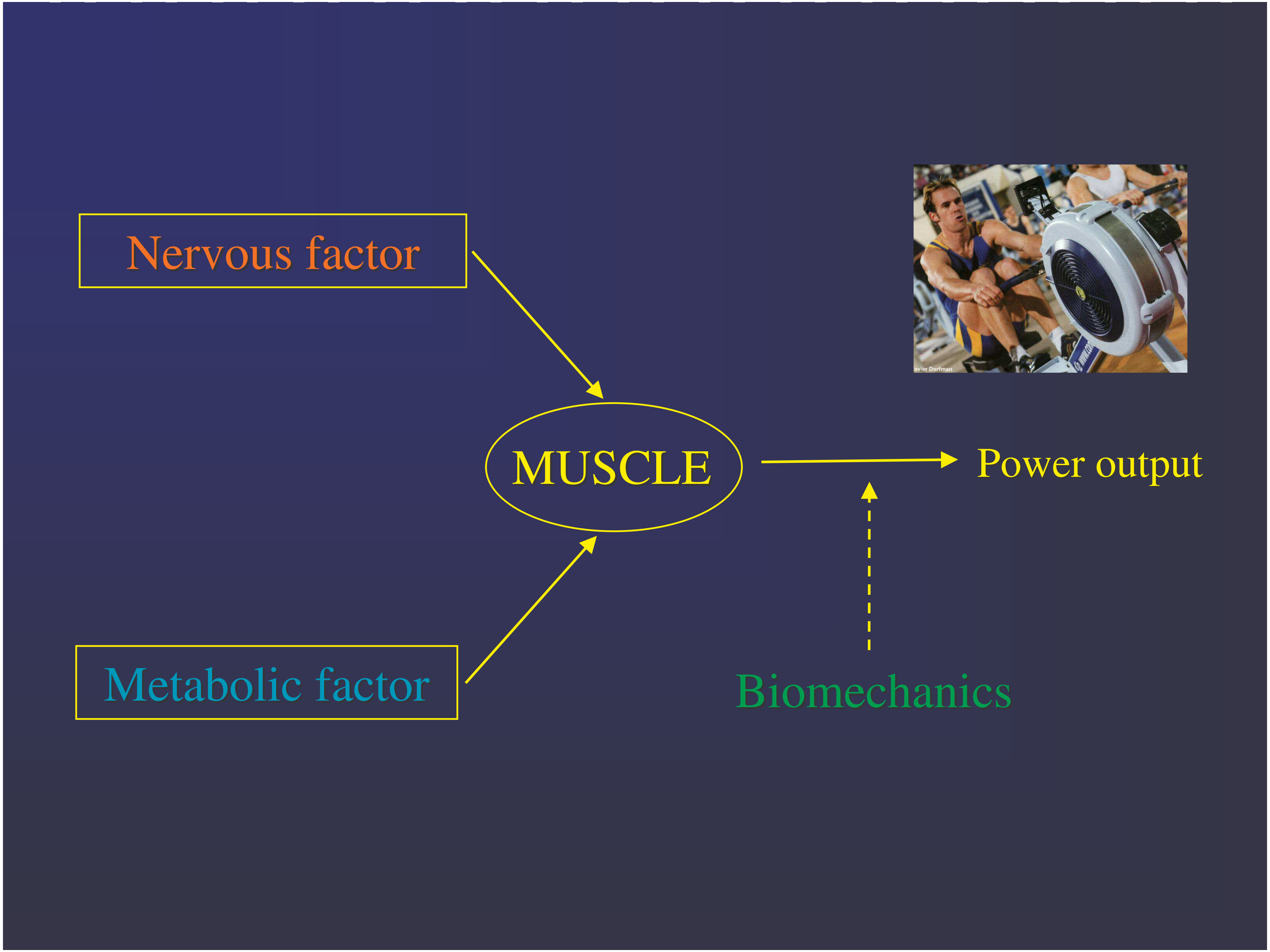
Purpose of laboratory testing

↓

Training aid to improve performance

Effective testing characteristics

1- Measured variables should be relevant to activity


Nervous factor
MUSCLE
Power output
Metabolic factor
Biomechanics

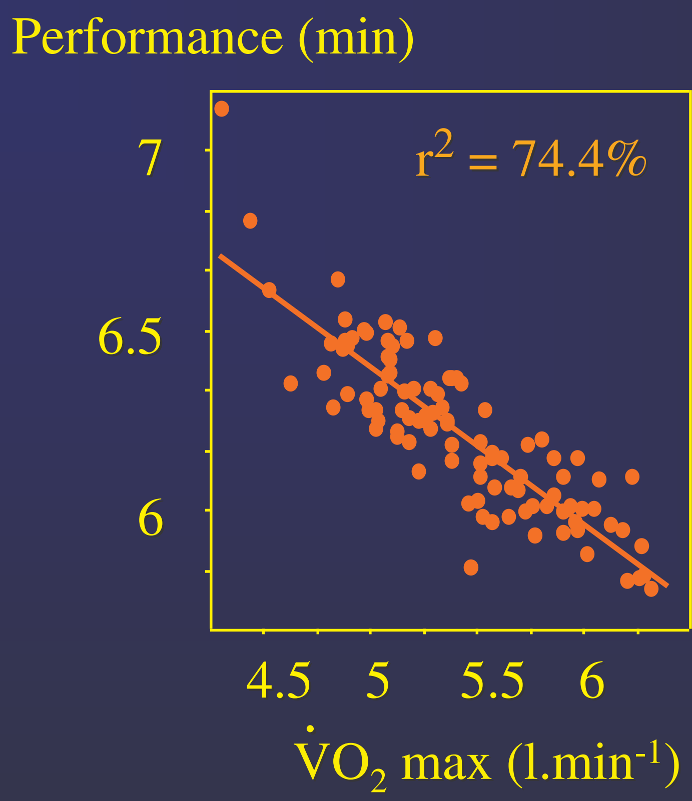
75-80% aerobic source

20-25% anaerobic source

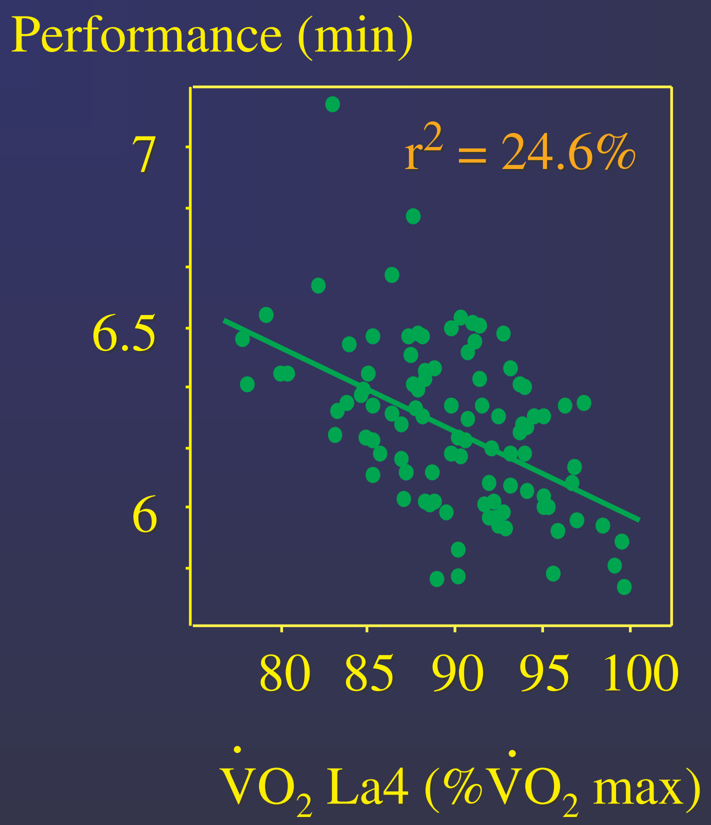
Total metabolic energy for on-water rowing performance

Hagerman at al. (1978, 1984)

Maximal oxygen consumption: $\dot{V}O_2max$



Lactate threshold



Effective testing characteristics

1- Measured variables should be relevant to activity

$\dot{V}O2max$ and blood lactate kinetic

2- Measurements should be valid and reliable

$\dot{V}O_2$ measurement systems

Reference method

Advantage: measurement error < 3%

Disadvantage: time consuming

Breath-by-breath respiratory systems

Avantage: automated

Disadvantage: poor accuracy for power > 200-250 W

Blood lactate concentration measurement

Venous catheter

Advantage: accuracy

Disadvantage: invasive - time consuming

Micro-method

Advantage: non invasive - good accuracy

Disadvantage: time consuming (2 min/analysis)

Portable systems

Advantage: non invasive - immediate result

Disadvantage: consumable expensive - poor accuracy

YSI2300	Portable system	%variation
0,6	1,7	*169,8*
0,7	2,9	*302,8*
1,8	2,8	*56,4*
2,0	2,5	*26,9*
2,1	2,6	*25,0*
2,1	2,9	*38,1*
2,1	2,7	*26,2*
2,3	2,6	*13,5*
2,4	3,1	*27,0*
2,7	2,6	*-4,8*
2,7	3,3	*20,4*
3,3	4,4	*35,0*
3,6	3,6	*0,0*
3,7	9,2	*150,7*
5,4	5,6	*3,1*
5,5	6,1	*10,1*
9,0	11,2	*24,4*
9,8	12,8	*30,6*
9,9	9,6	*-2,7*
11,6	12,2	*5,2*

→ Possible use for training control not for threshold determination

Testing protocol

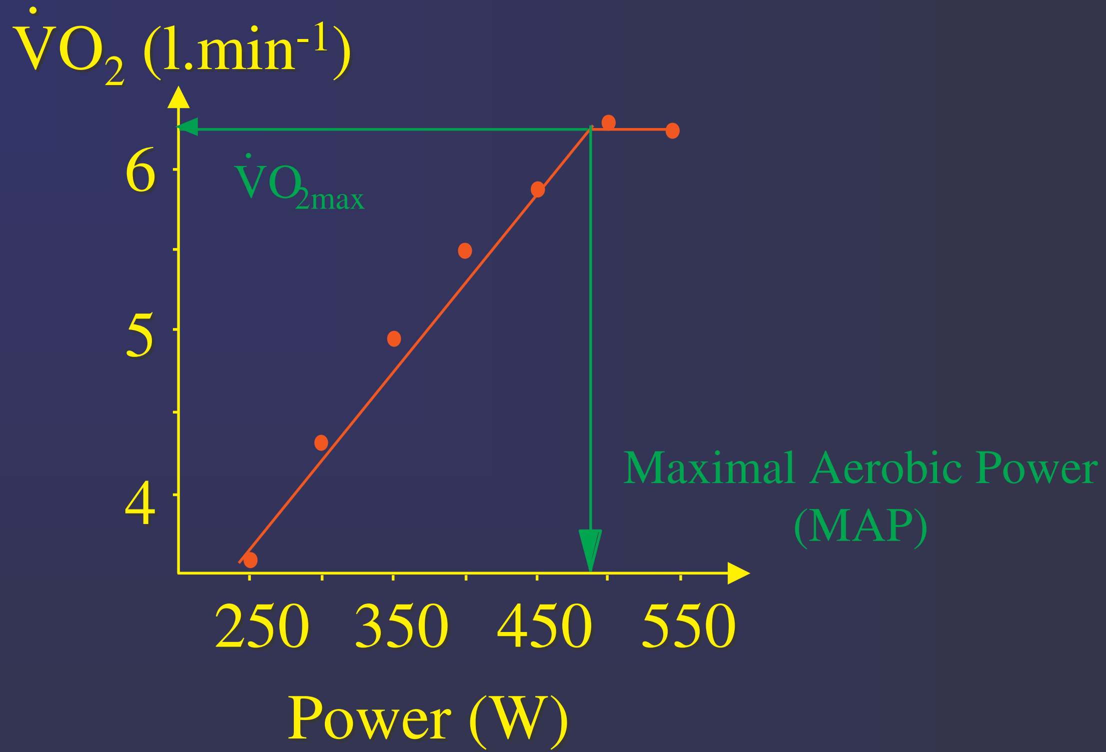
- In october/november

- 5 min warm-up at power ranging between 150 and 200 W

- 3 min bouts, 50 W increment for men and 30 W for women

- 30 sec rest between bout for blood taking at ear lobe

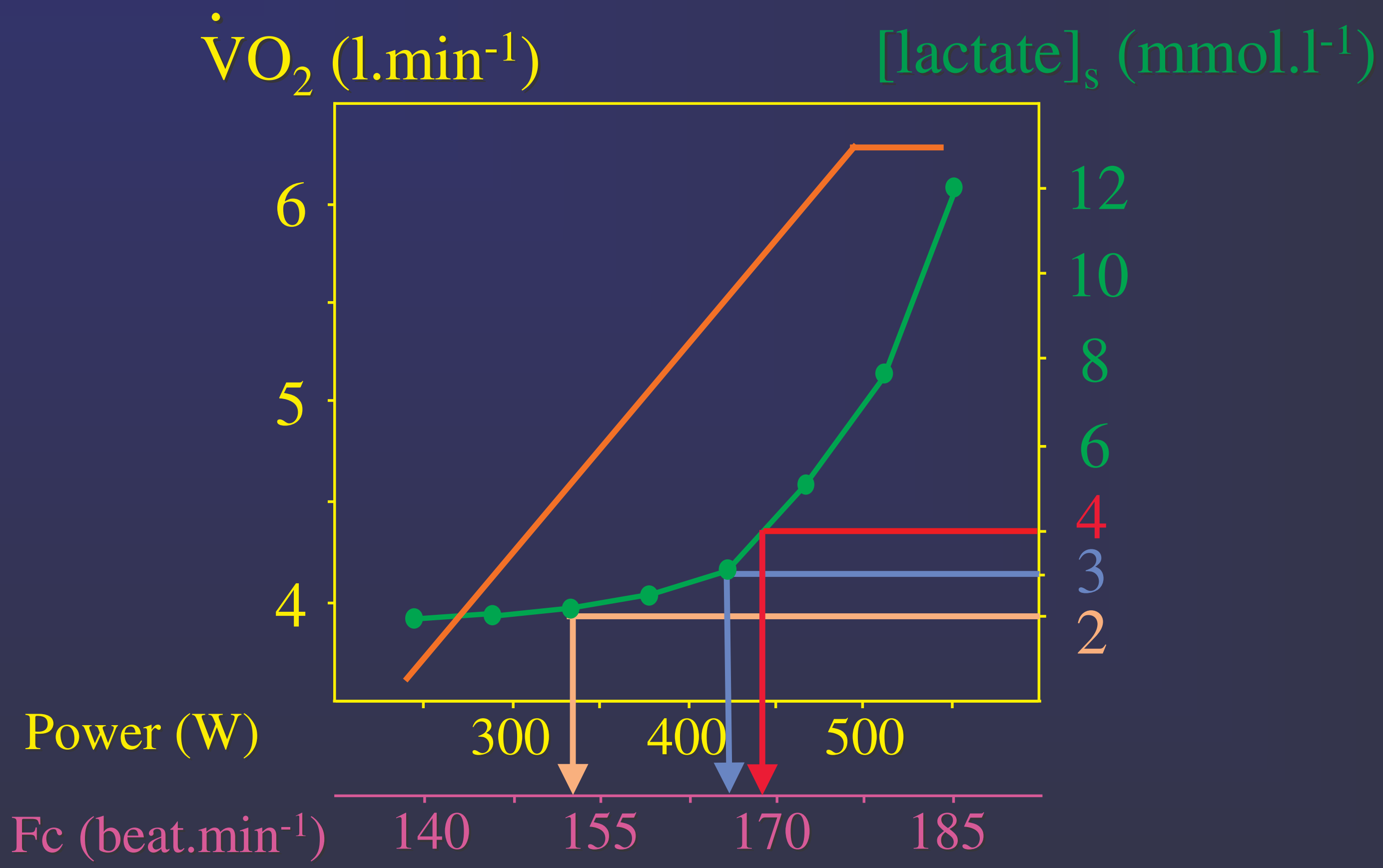
QuickTime™ et un
décompresseur codec YUV420
sont requis pour visionner cette image.

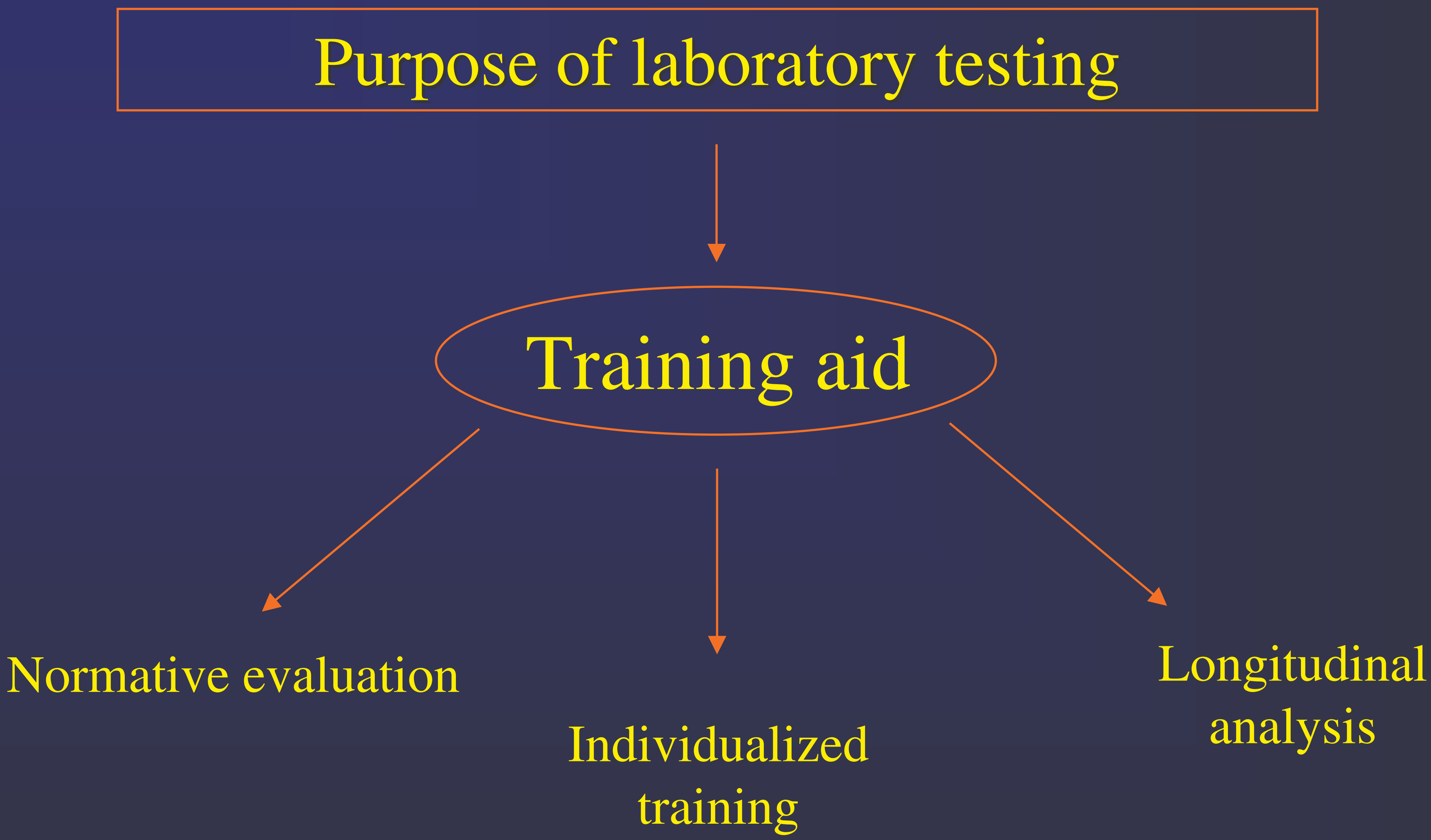


V̇O2 (l.min-1)
6
5
4
V̇O2max
Maximal Aerobic Power
(MAP)
250 350 450 550
Power (W)

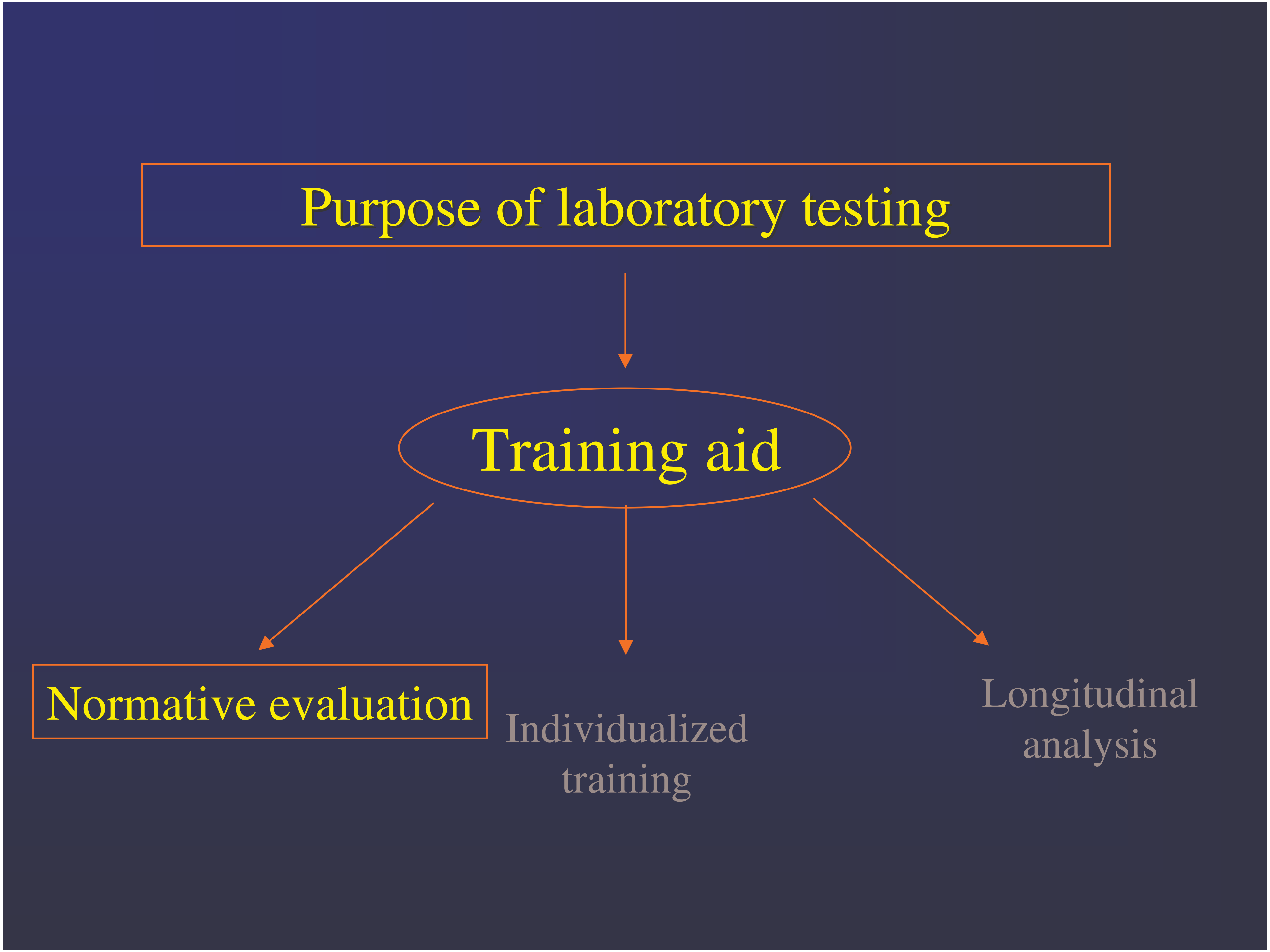
QuickTime™ et un
décompresseur codec YUV420
sont requis pour visionner cette image.

Tresholds détermination





Purpose of laboratory testing
Training aid
Normative evaluation
Individualized training
Longitudinal analysis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Normative evaluation

International level

	Body mass	$\dot{V}O_{2max}$	$\dot{V}O_2La4\%$
HW	90.8 kg	6 $l.min^{-1}$	88%
LW	72.3 kg	5.3 $l.min^{-1}$	85%

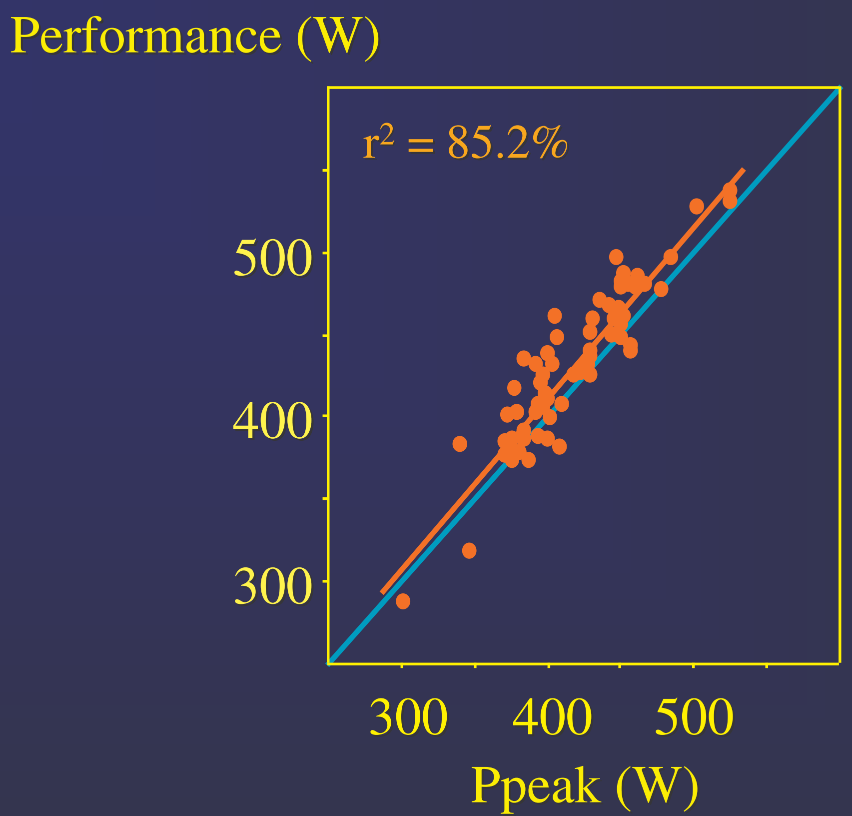
Laboratory testing is time consuming and costly

Validation of a test for field evaluation

Ppeak determination

Snoeckx et coll. (1983)

$$\text{Ppeak} = \text{P last completed bout} + \frac{\text{T last bout}}{\text{T total bout}} \times \Delta P$$



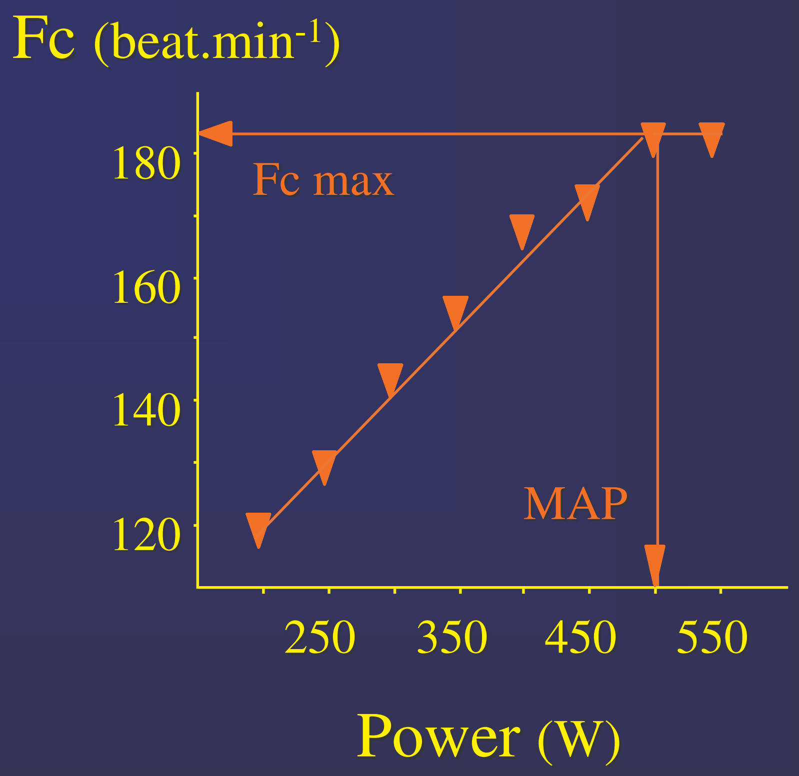
Performance (W)
r2 = 85.2%
500
400
300
300
400
500
Ppeak (W)

Factors influencing Ppeak

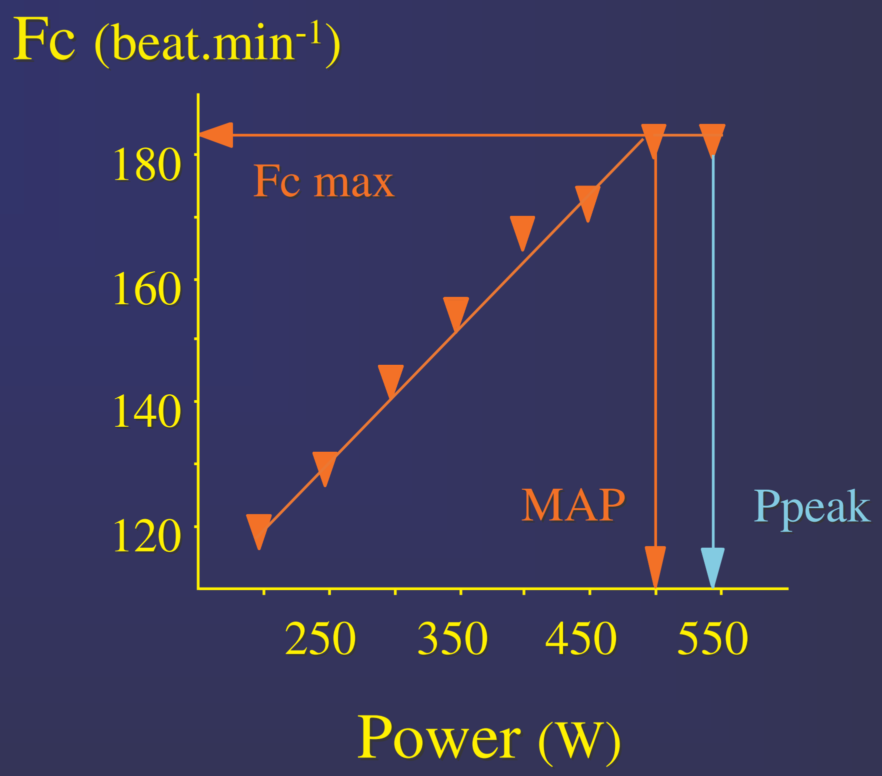
- $\dot{V}O_{2max}$
- $\dot{V}O_2La4\%$
- Efficiency (mechanical power/metabolic power)
- Motivation

Conclusion:

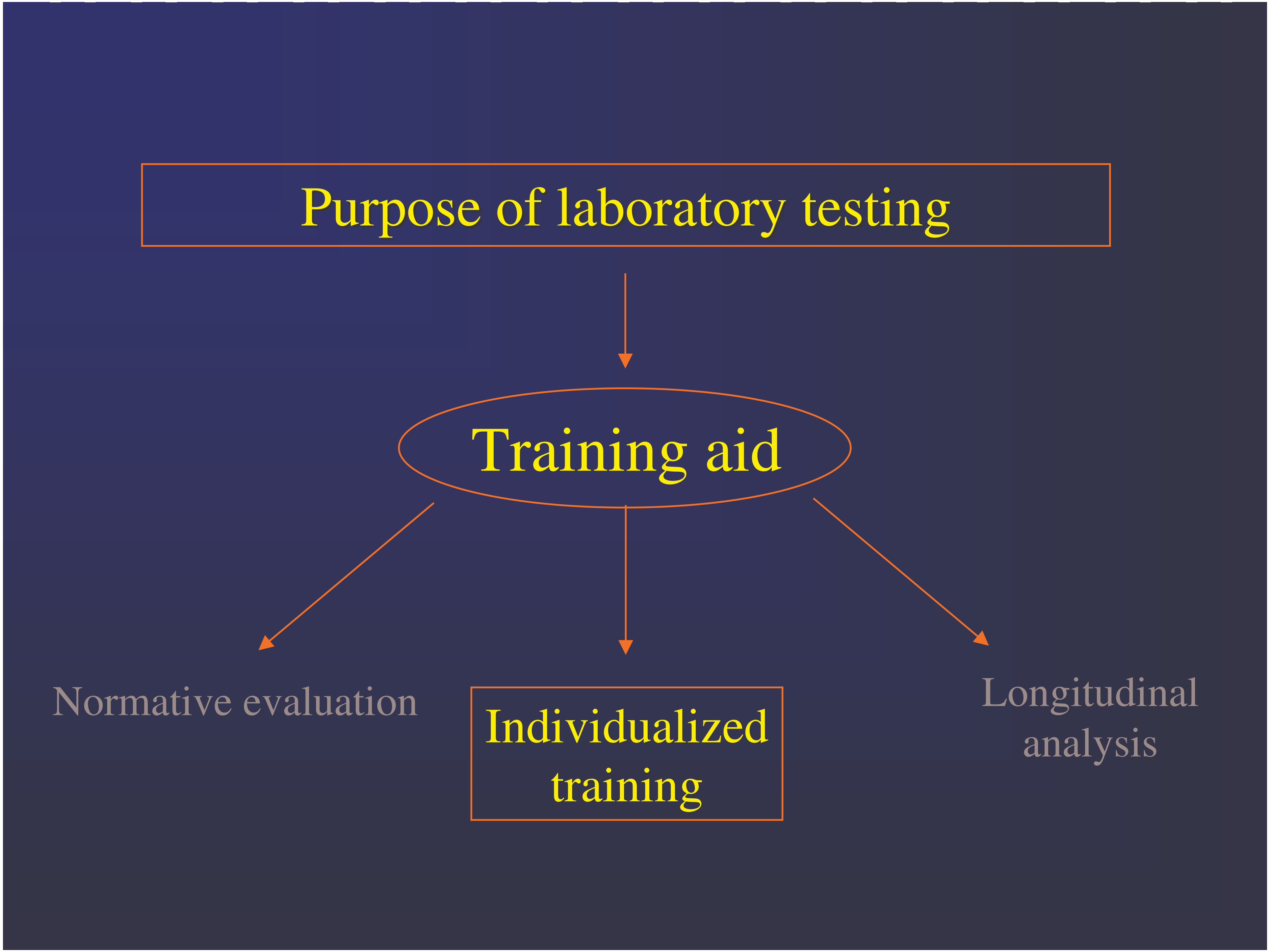
Ppeak is a global index of rowing ergometer performance



MAP corresponds to $\dot{V}O_{2max}$



Difference between Ppeak and MAP is a good index of anaerobic capacity



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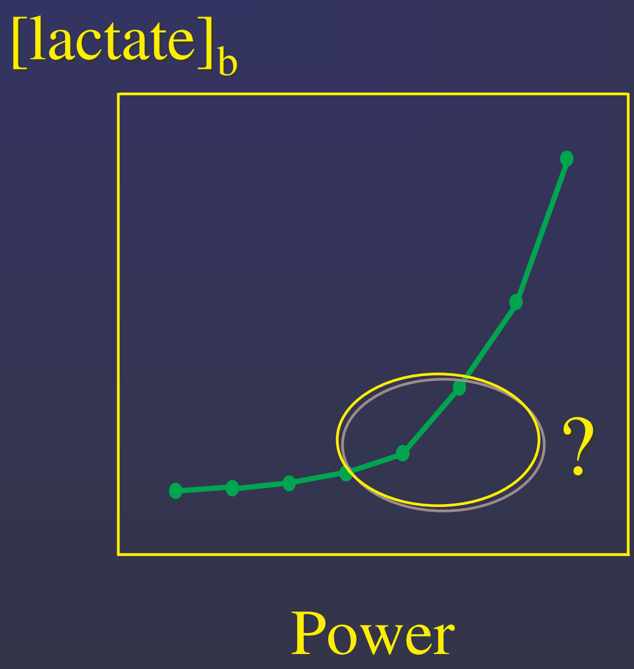
Individualized training

Training intensity is controlled by using Fc and power corresponding to 2, 3 and 4 $mmol.l^{-1}$ of blood lactate concentration

Limits of Testing protocol

1- The concept of lactate threshold



Threshold concept (Kinderman, 1979)

-Aerobic threshold

↳ blood lactate concentration = 2 $mmol.l^{-1}$

Aerobic 98.5% Anaerobic 1.5%

-Transition aerobic-anaerobic

↳ blood lactate concentration between 2 and 4 $mmol.l^{-1}$

Aerobic 95% Anaerobic 5%

- Anaerobic threshold

↳ blood lactate concentration = 4 $mmol.l^{-1}$

Aerobic 91% Anaerobic 9%

[Lactate]
(mmol.l-1)
350 W
300 W
Training zone
8
7
6
5
4
3
2
1
3
6
9
12
15
18
21
time (min)

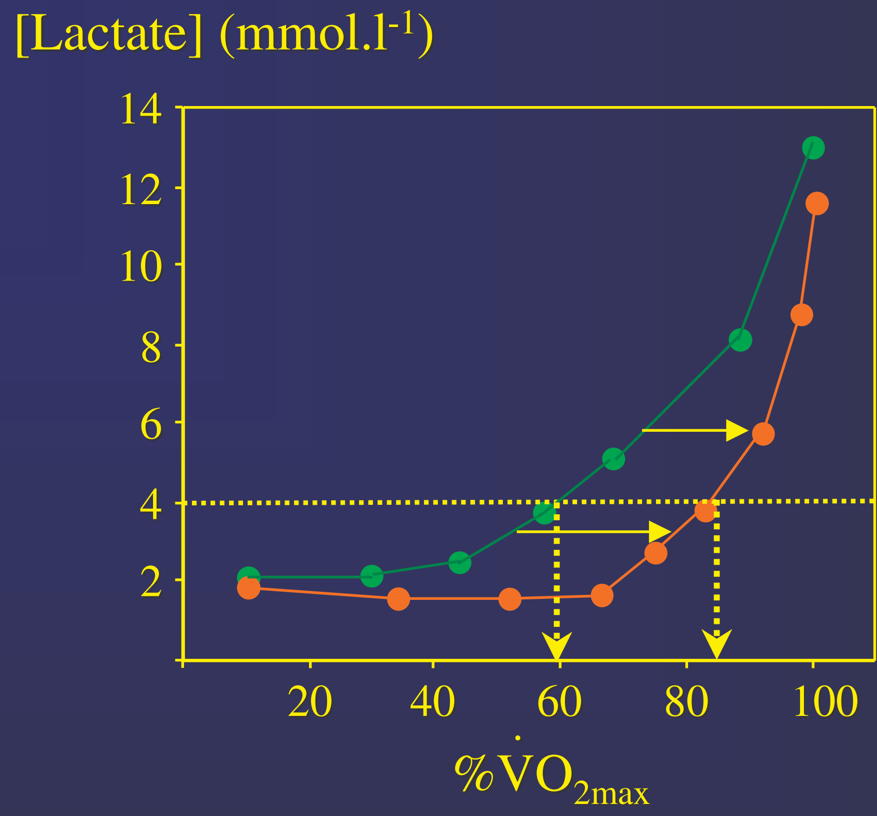
Maximal lactate steady state varies according to activity

(Beneke et von Duvillard, 1996)

Rowing : 3.1±0.5 $mmol.l^{-1}$

Cycling : 5.4±1 $mmol.l^{-1}$

Skating around : 6.6±0.9 $mmol.l^{-1}$

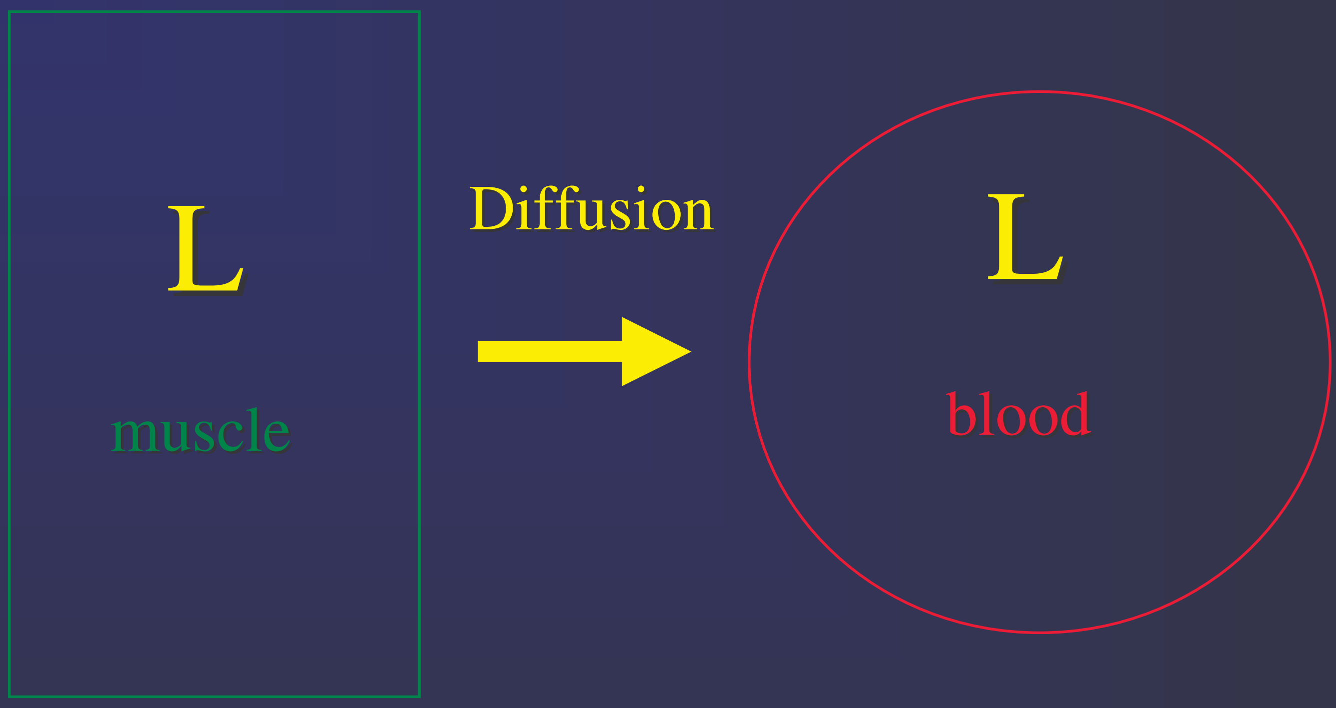


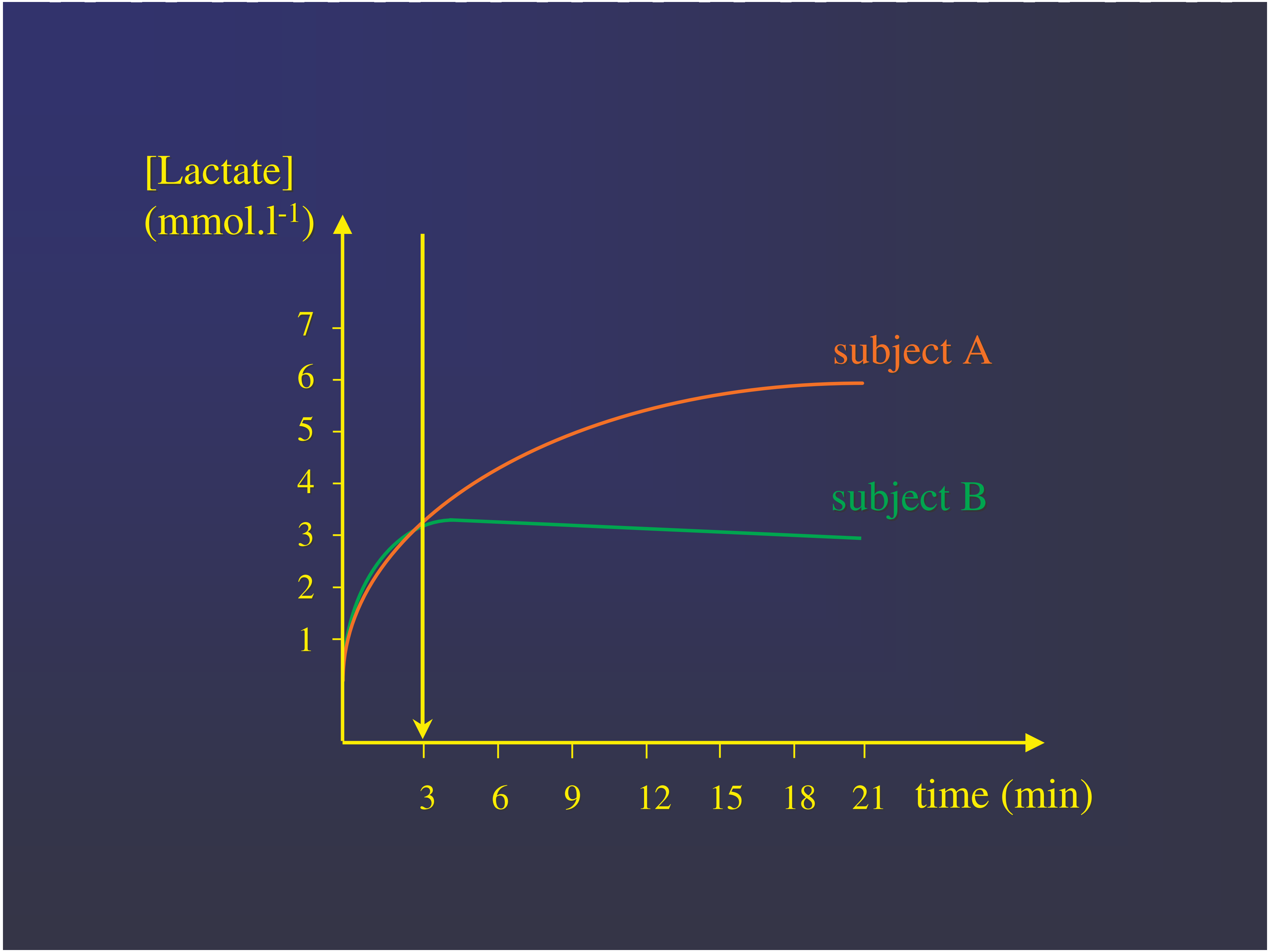
4 mmol.l-1 lactate threshold is an index of the shift to the right of lactate kinetic

Limits of Testing protocol

1- The concept of lactate threshold

2- Bout duration *vs* increment


L
muscle
Diffusion
L
blood


[Lactate]
(mmol.l-1)
7
6
5
4
3
2
1
subject A
subject B
3
6
9
12
15
18
21
time (min)

To sum up…

- In rowing maximal lactate steady state could vary between 2 and 4 $mmol.l^{-1}$ *(Beneke et al, 1996)*

- Short boot duration and high power increment could not permit lactate diffusion from muscle to blood

↳ Overestimation of maximal lactate steady state

(Stockhausen et al, 1997)

French federal training program

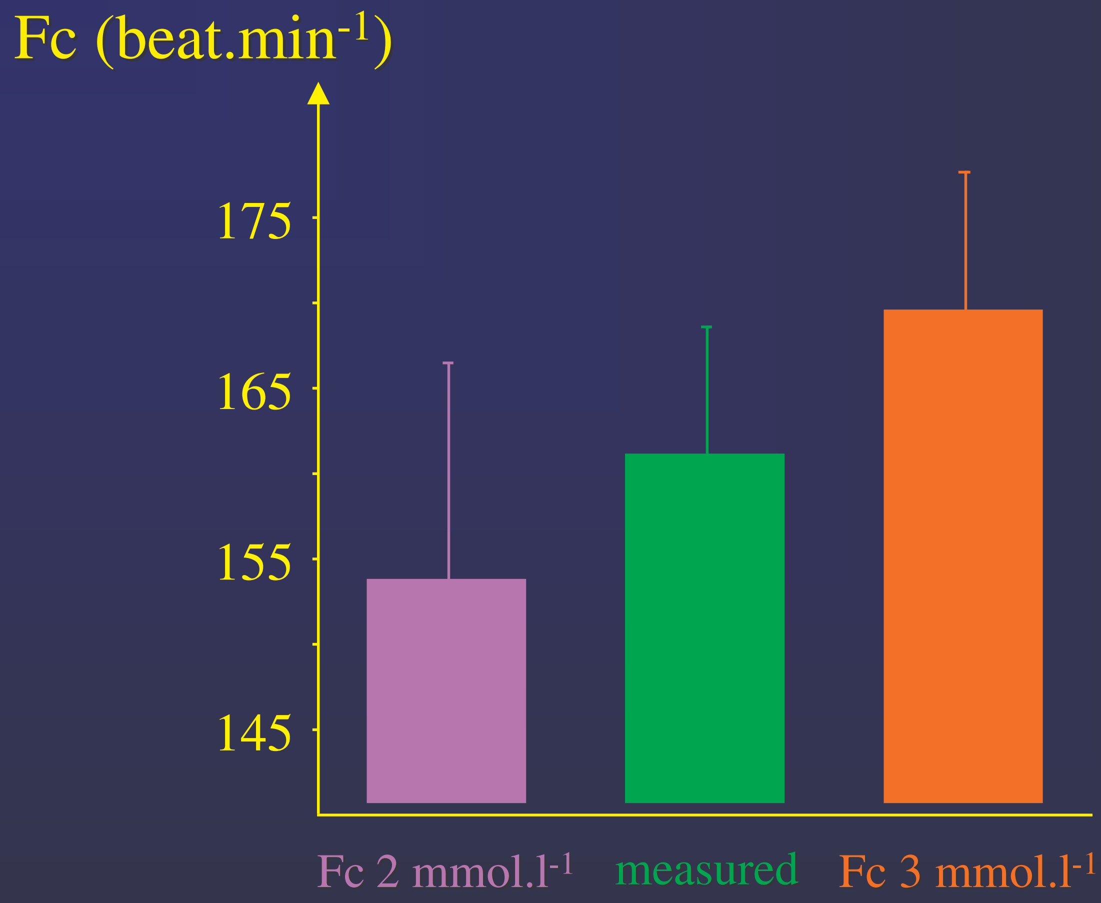
B1: 2 x 45 min, $[\text{lactate}]_b \leq 2$ mmol.l^{-1}

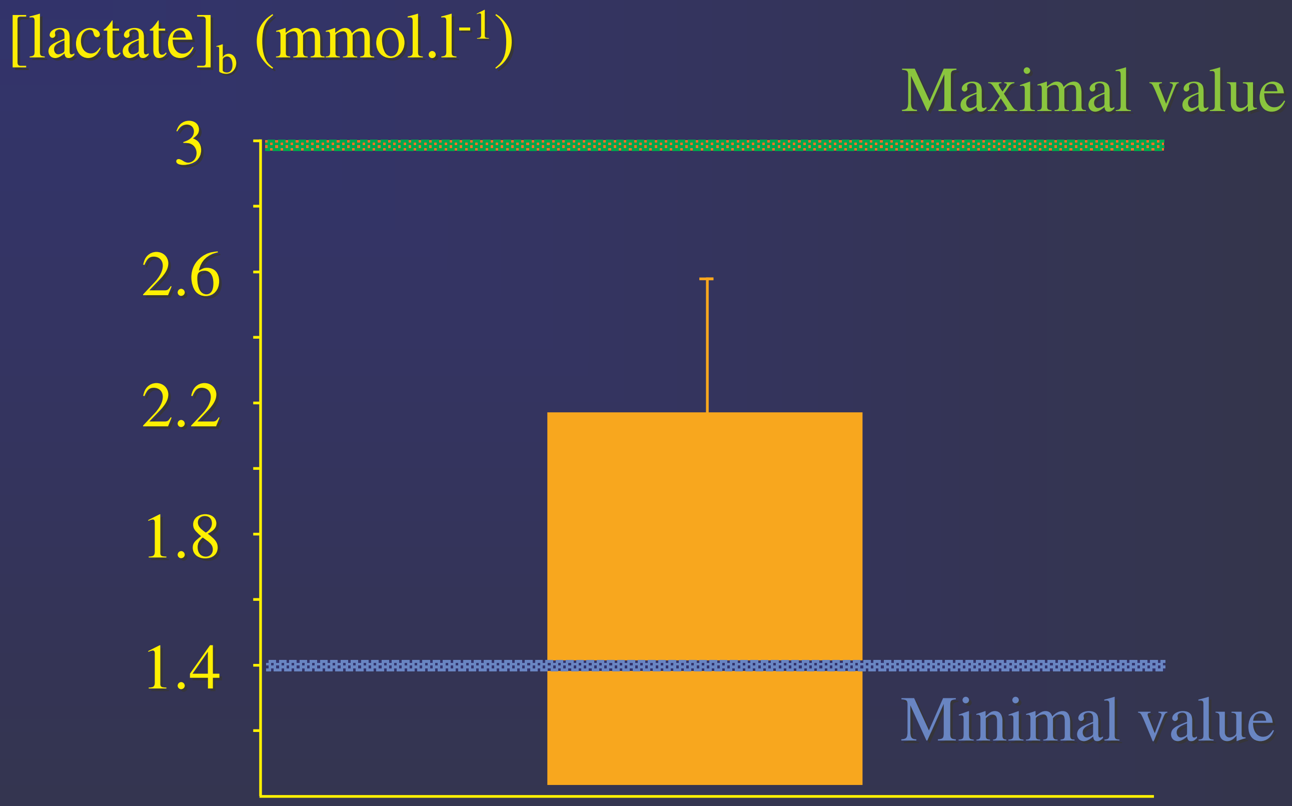
B2: 2 x 30 min, $2 \leq [\text{lactate}]_b \leq 3$ mmol.l^{-1}

↓

Around 80% of annual total training volume

Training control in boat


Fc (beat.min-1)
175
165
155
145
Fc 2 mmol.l-1
measured
Fc 3 mmol.l-1


[lactate]b (mmol.l-1)
Maximal value
3
2.6
2.2
1.8
1.4
Minimal value

Training control during ergometer training

Difficulties to maintain power corresponding to 2 and 3 $mmol.l^{-1}$ during ergometer training

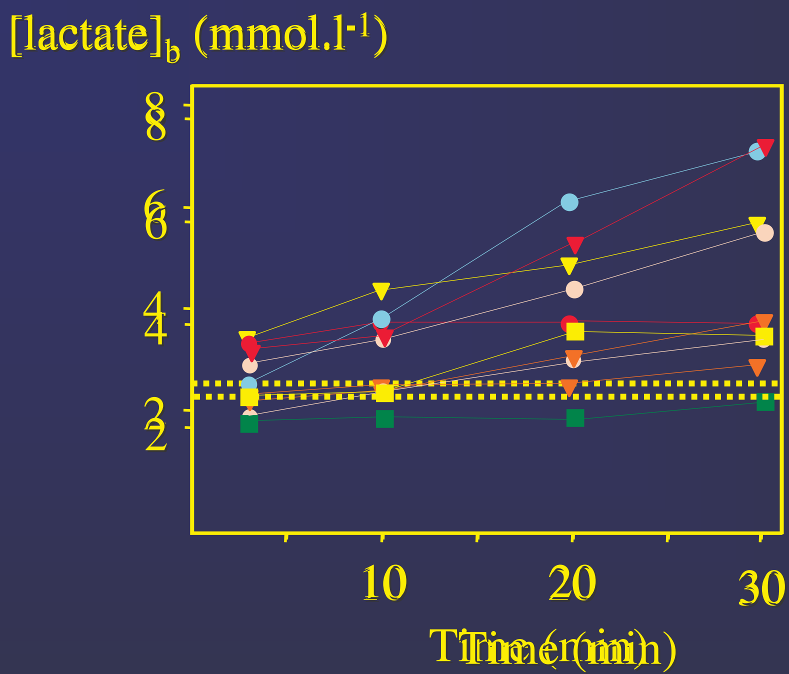
↓

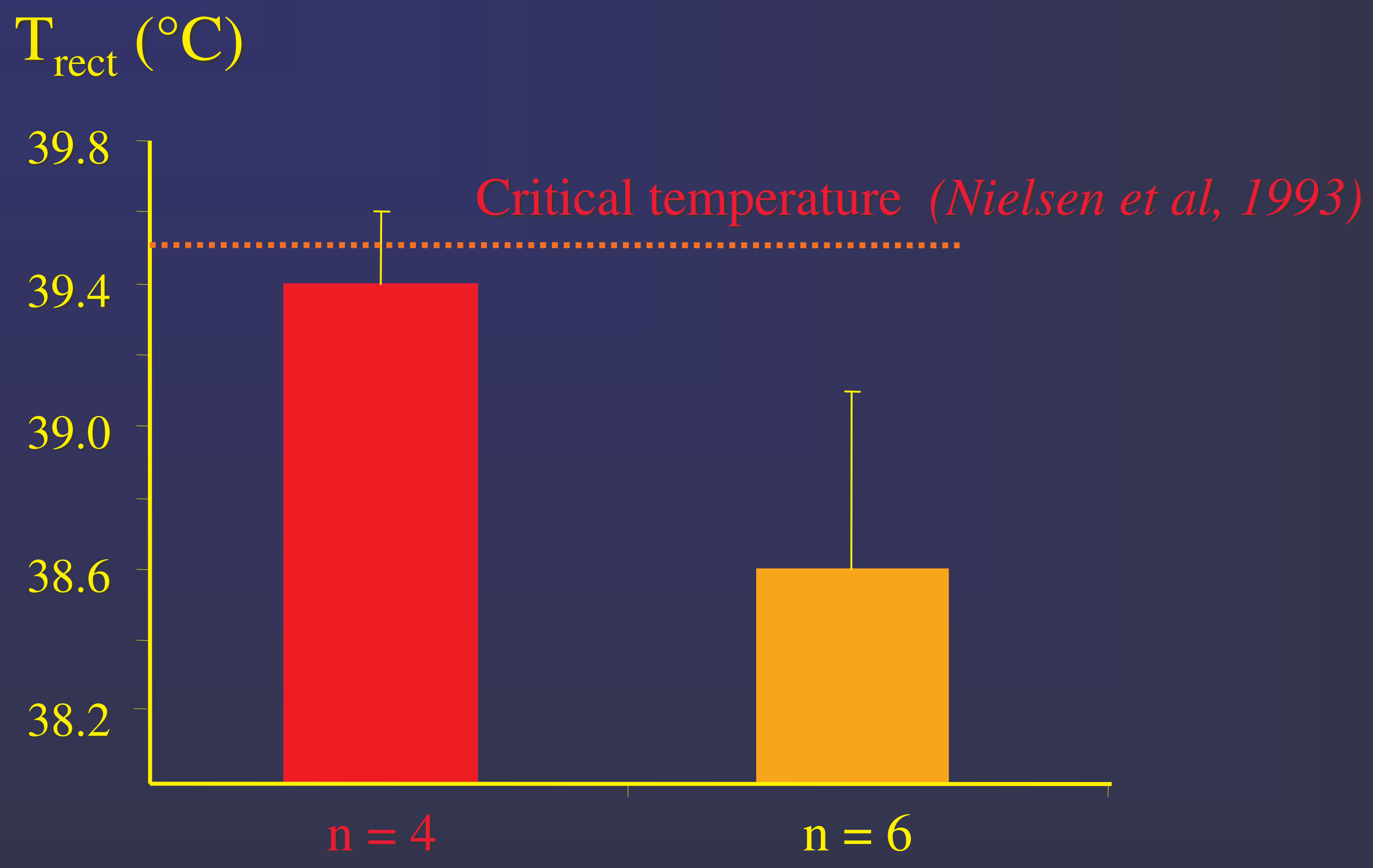
Hypothesis:

Blood lactate accumulation and/or thermoregulation troubles could occur

- 10 rowers
- 2 x 30 min at power corresponding to 2.5 mmol.l^{-1}
- Measurement of Fc, RPE, $[\text{lactate}]_b$ and rectal temperature
- Ambient temperature 15°C

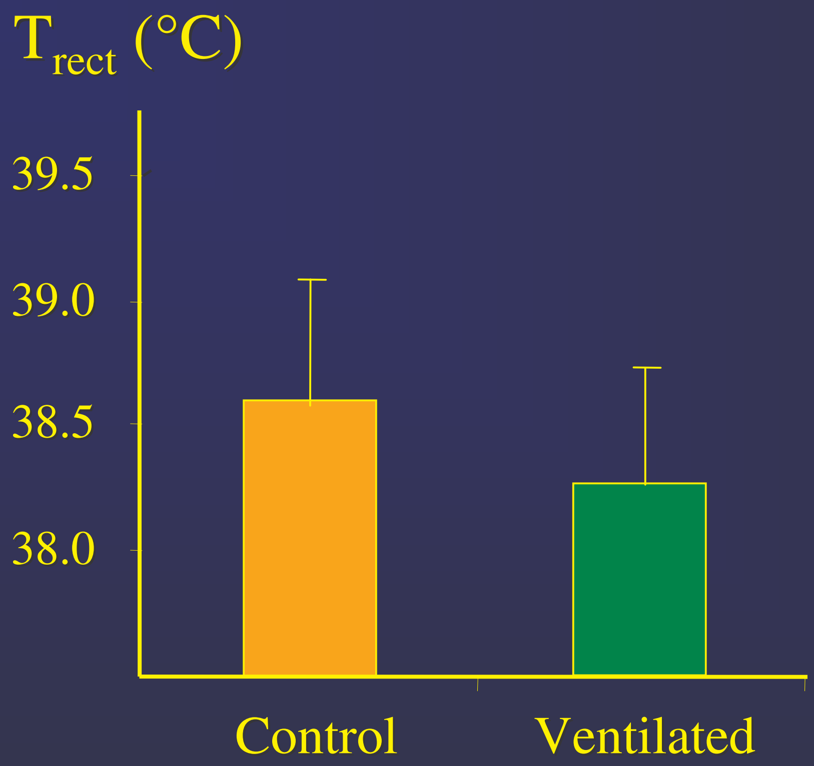
Maciejewski et al (2007)


[lactate]$_b$ (mmol.l^{-1})
8
6
4
2
10
20
30
Time (min)

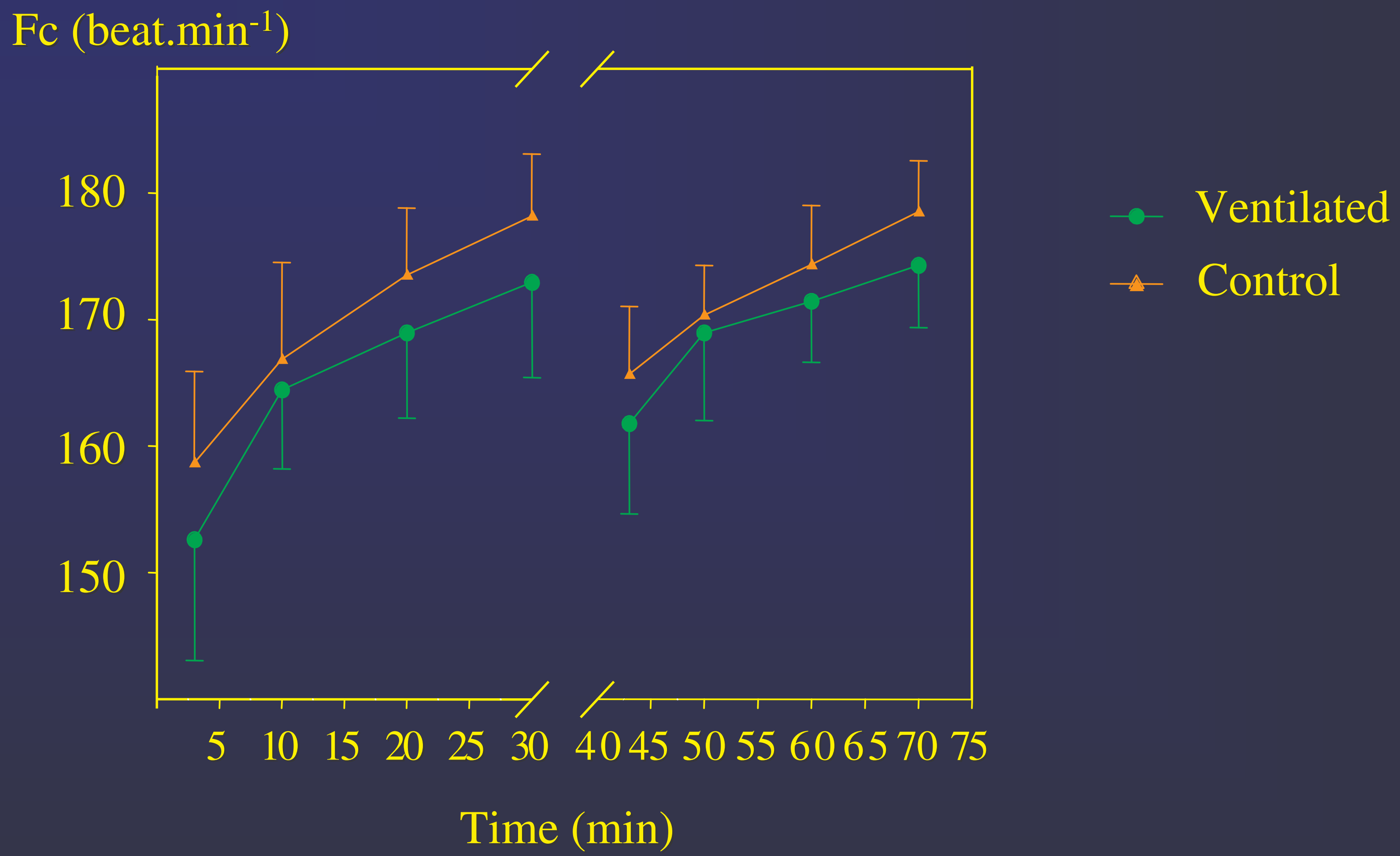


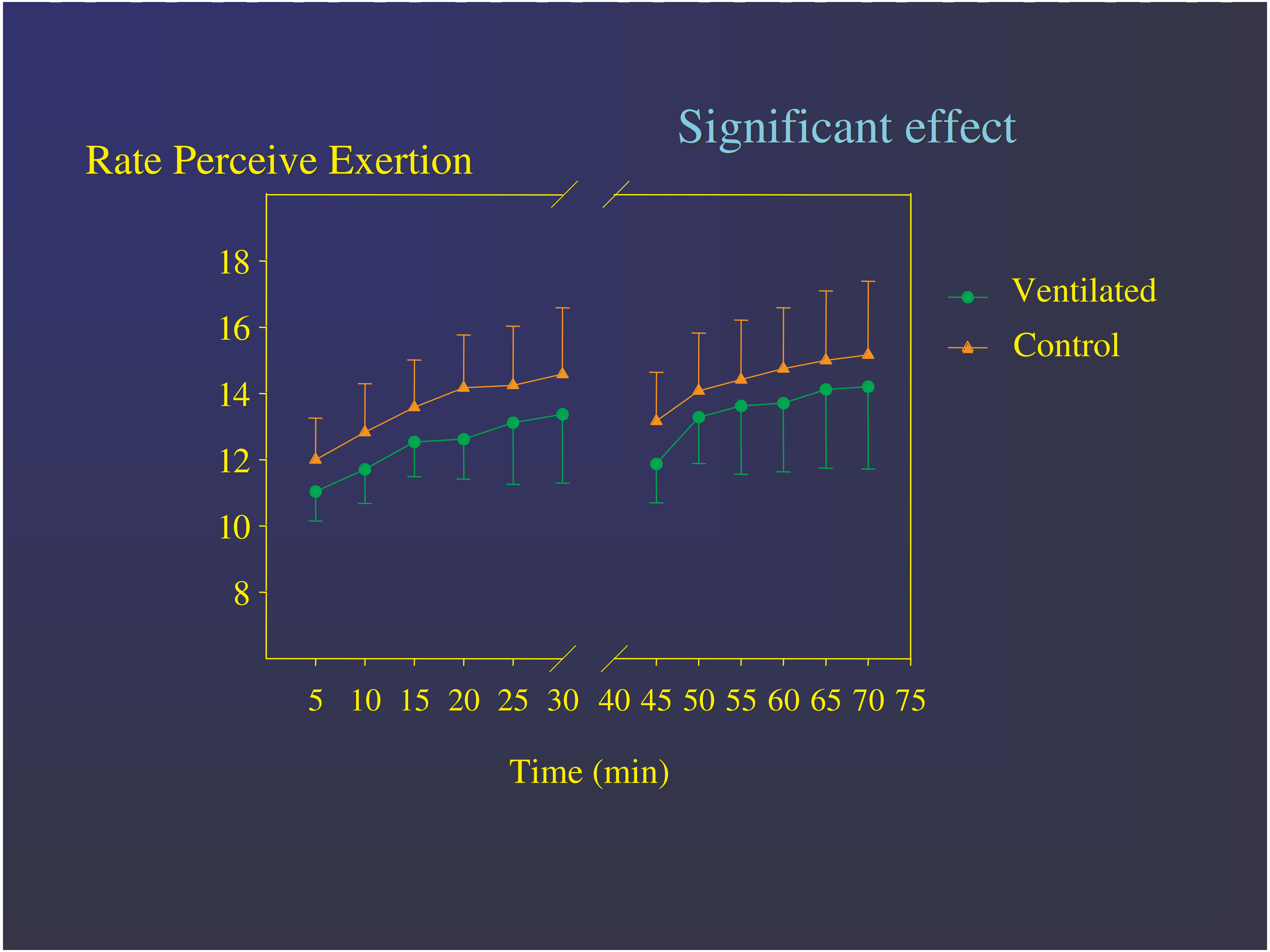
T rect (°C)
39.8
39.4
39.0
38.6
38.2
Critical temperature (Nielsen et al, 1993)
n = 4
n = 6

Influence of ventilation



Significant effect





Significant effect
Rate Perceive Exertion
18
16
14
12
10
8
Ventilated
Control
5 10 15 20 25 30 40 45 50 55 60 65 70 75
Time (min)

Conclusion

Rowing ergometer training should be made with ventilation and/or outside…

Field testing and training monitoring

For young club rowers (15-17 years old)

B1: $[\text{lactate}]_b \leq 2\ \text{mmol.l}^{-1}$

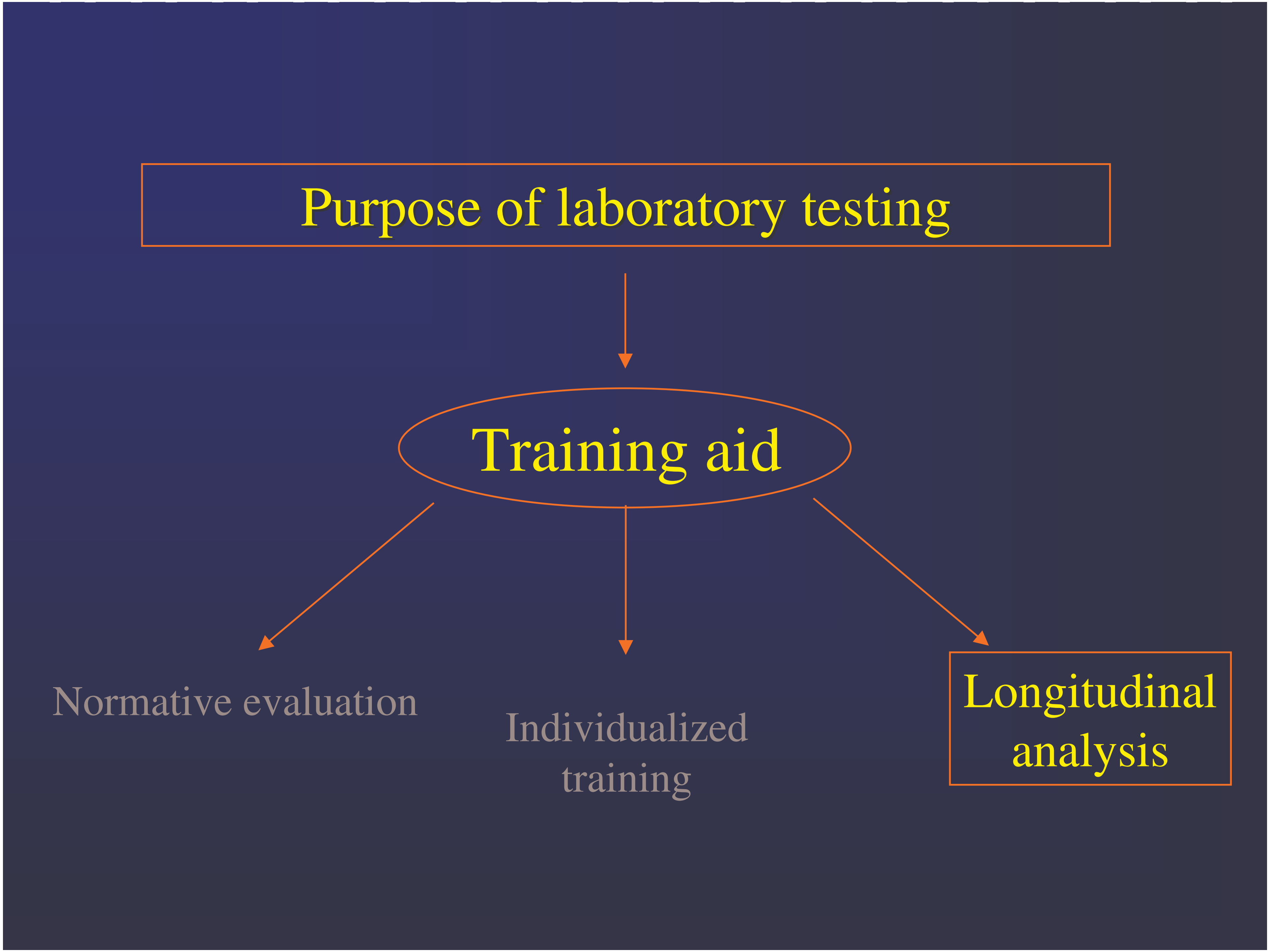
↓

80% of maximal Fc

B2: $2 \leq [\text{lactate}]_b \leq 3\ \text{mmol.l}^{-1}$

↓

85% of maximal Fc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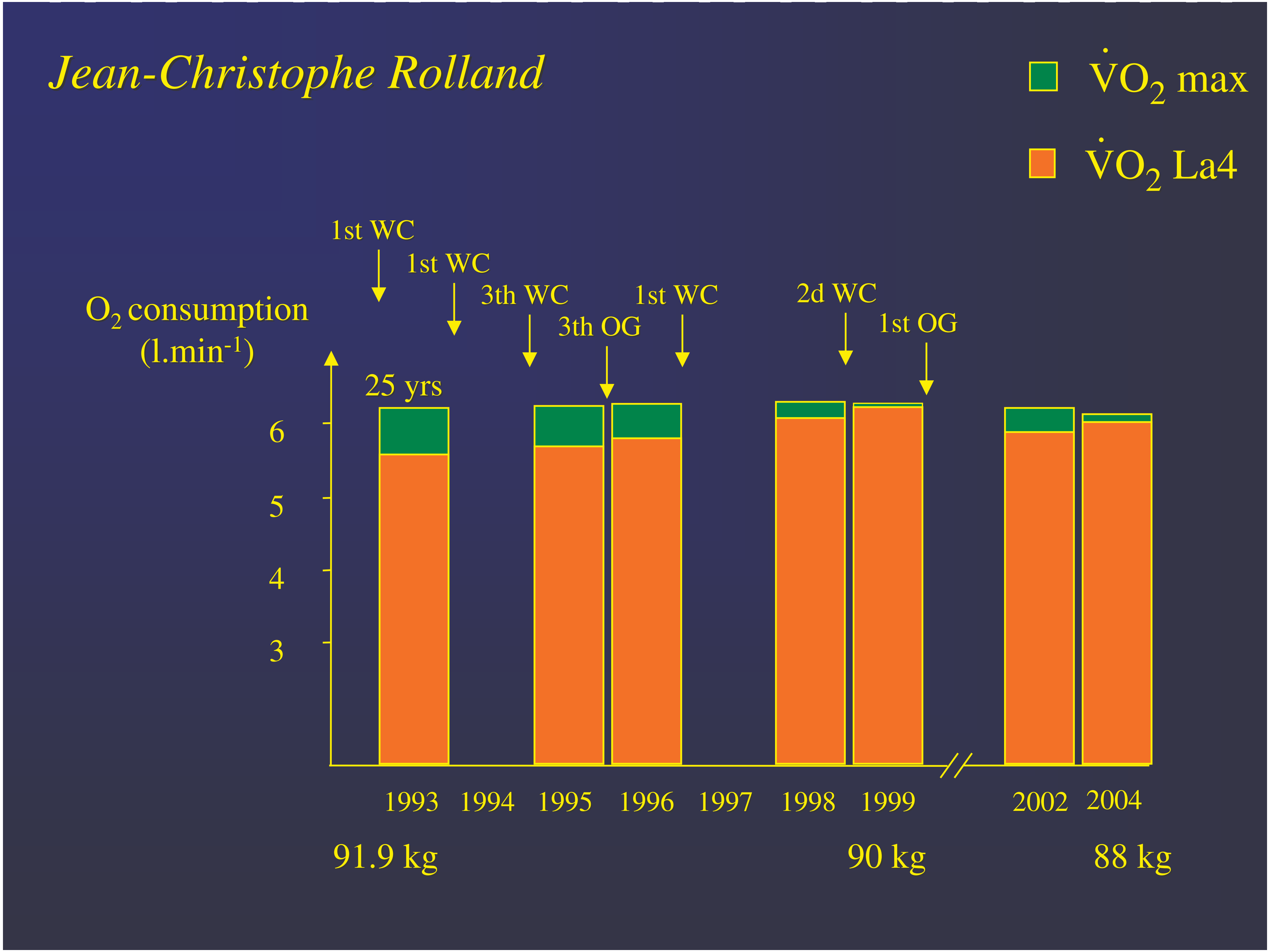
French team

Similar $\dot{V}O_{2max}$ related to body mass

4 mmol.l^{-1} threshold (% MAP)

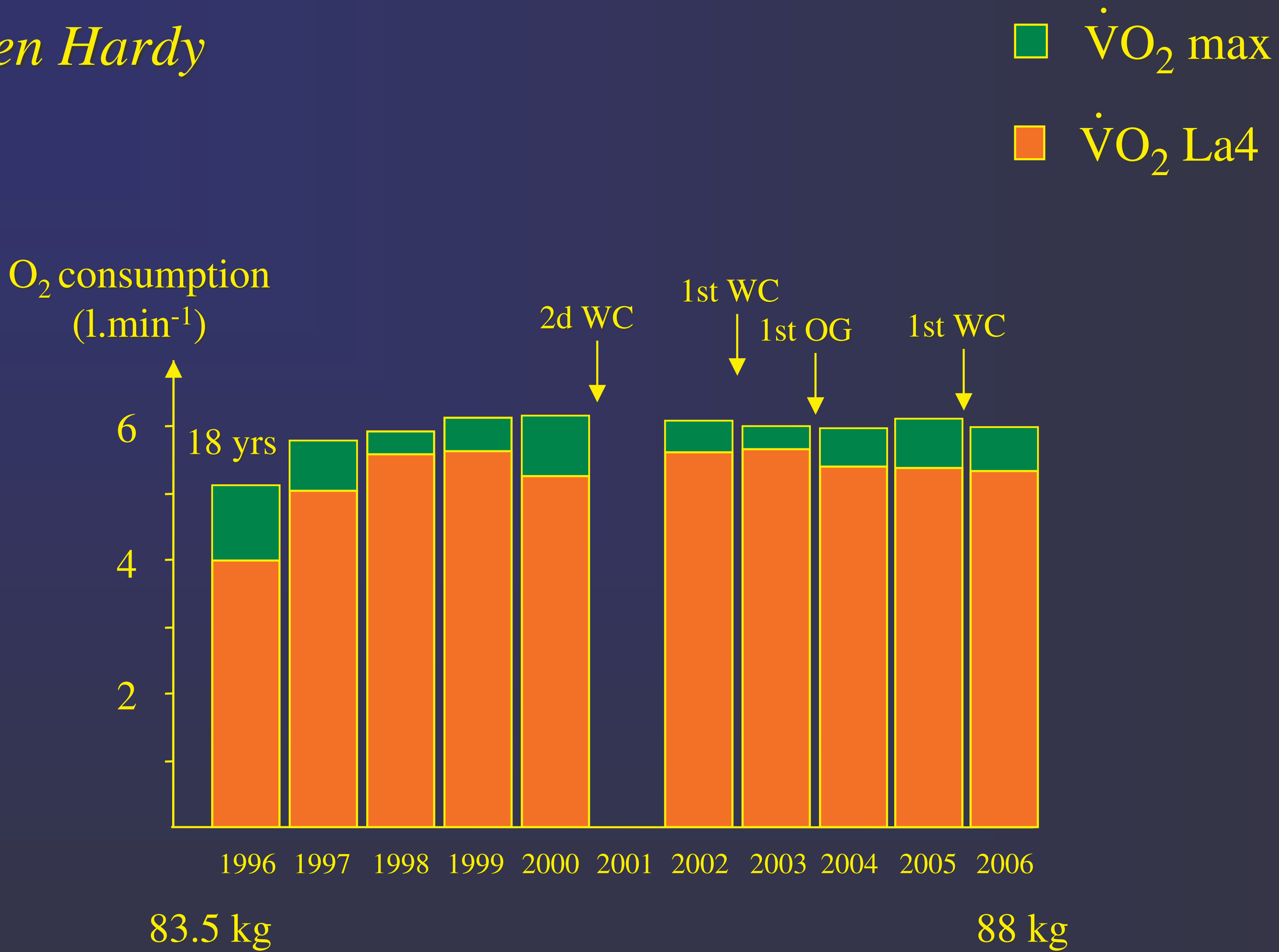
Training or bias?

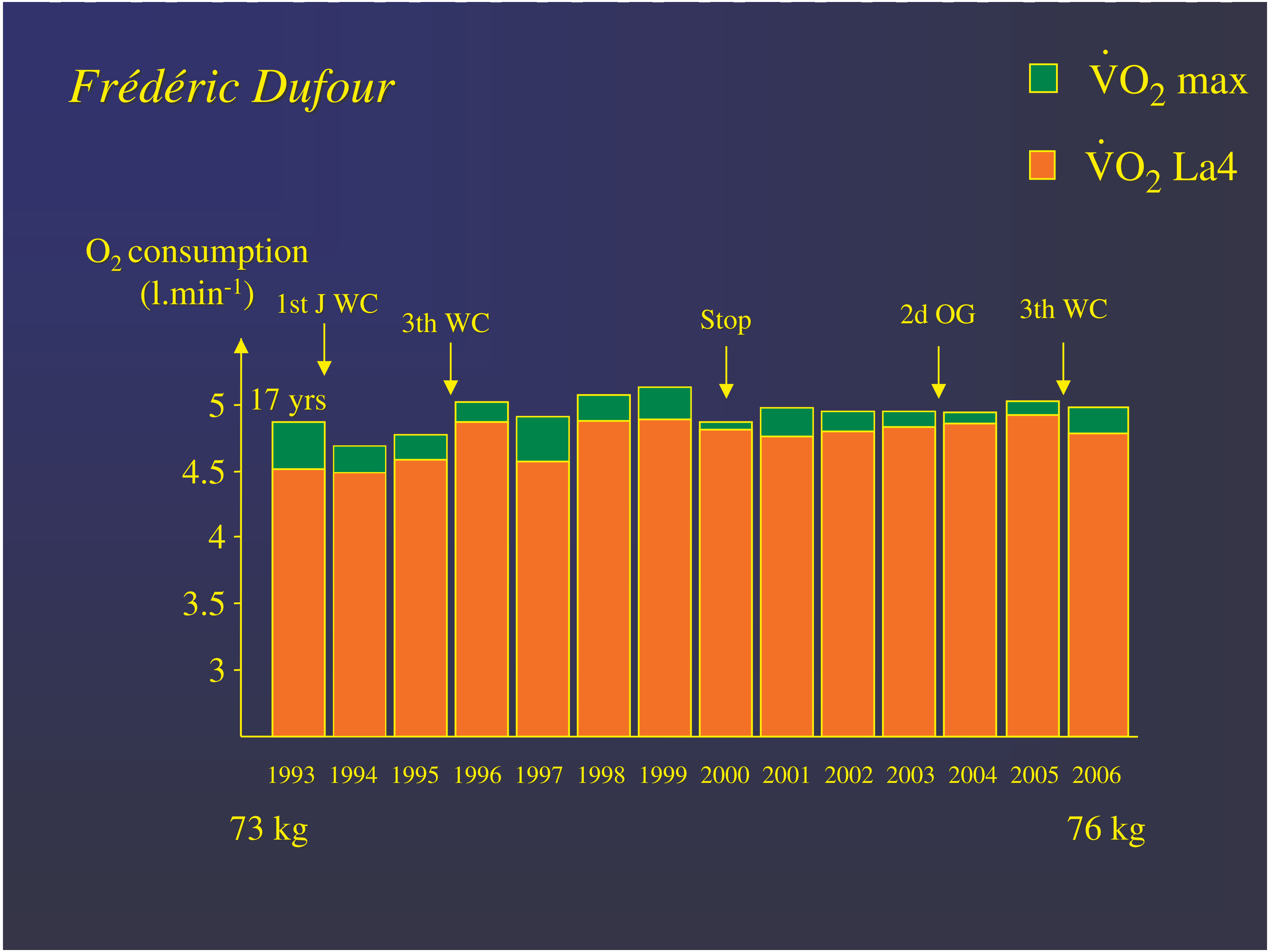
< 23 years		Senior A
82%	→	86%
72 kg		74 kg
85 kg		90 kg



Jean-Christophe Rolland
$\dot{V}O_2$ max
$\dot{V}O_2$ La4
O_2 consumption
($l.min^{-1}$)
1st WC
1st WC
3th WC
3th OG
1st WC
2d WC
1st OG
25 yrs
6
5
4
3
1993
1994
1995
1996
1997
1998
1999
2002
2004
91.9 kg
90 kg
88 kg

Adrien Hardy





Frédéric Dufour
VO2 max
VO2 La4
O2 consumption
(l.min-1)
1st J WC
3th WC
Stop
2d OG
3th WC
17 yrs
5
4.5
4
3.5
3
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
73 kg
76 kg

To sum up…

- Training increases body mass

- $\dot{V}O_{2max}$ increases until age of twenty years

- 4 mmol threshold varies steadily as a function of training volume

Physiological interpretation

VO_2La4 shows inter and intra-individual variations

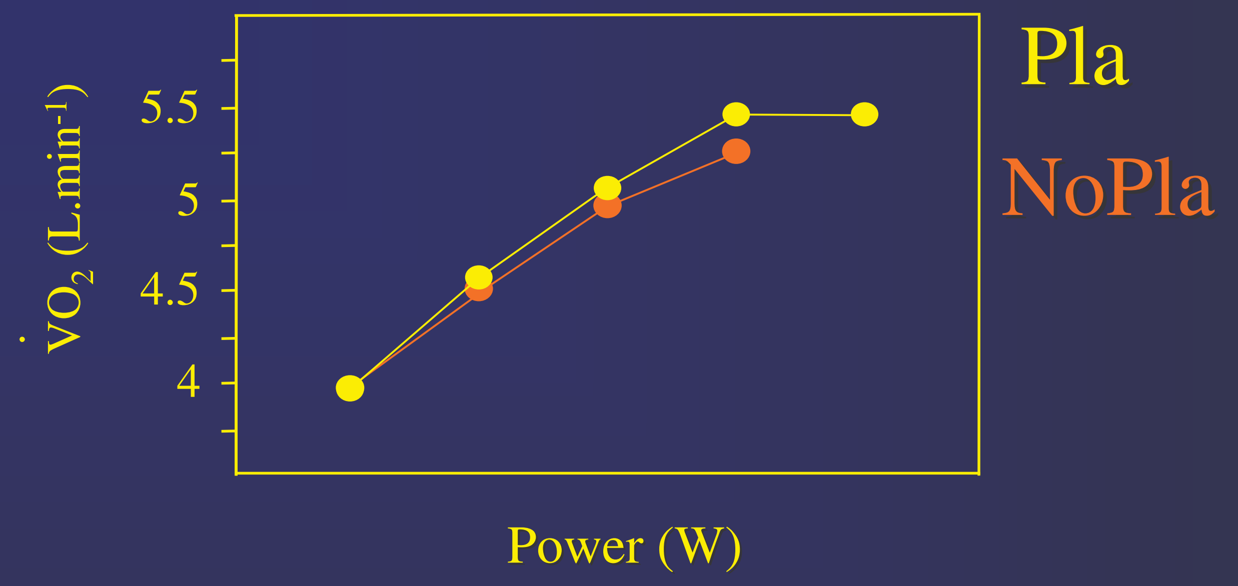
↓

↘ Lactate production and/or ↗ Lactate elimination?

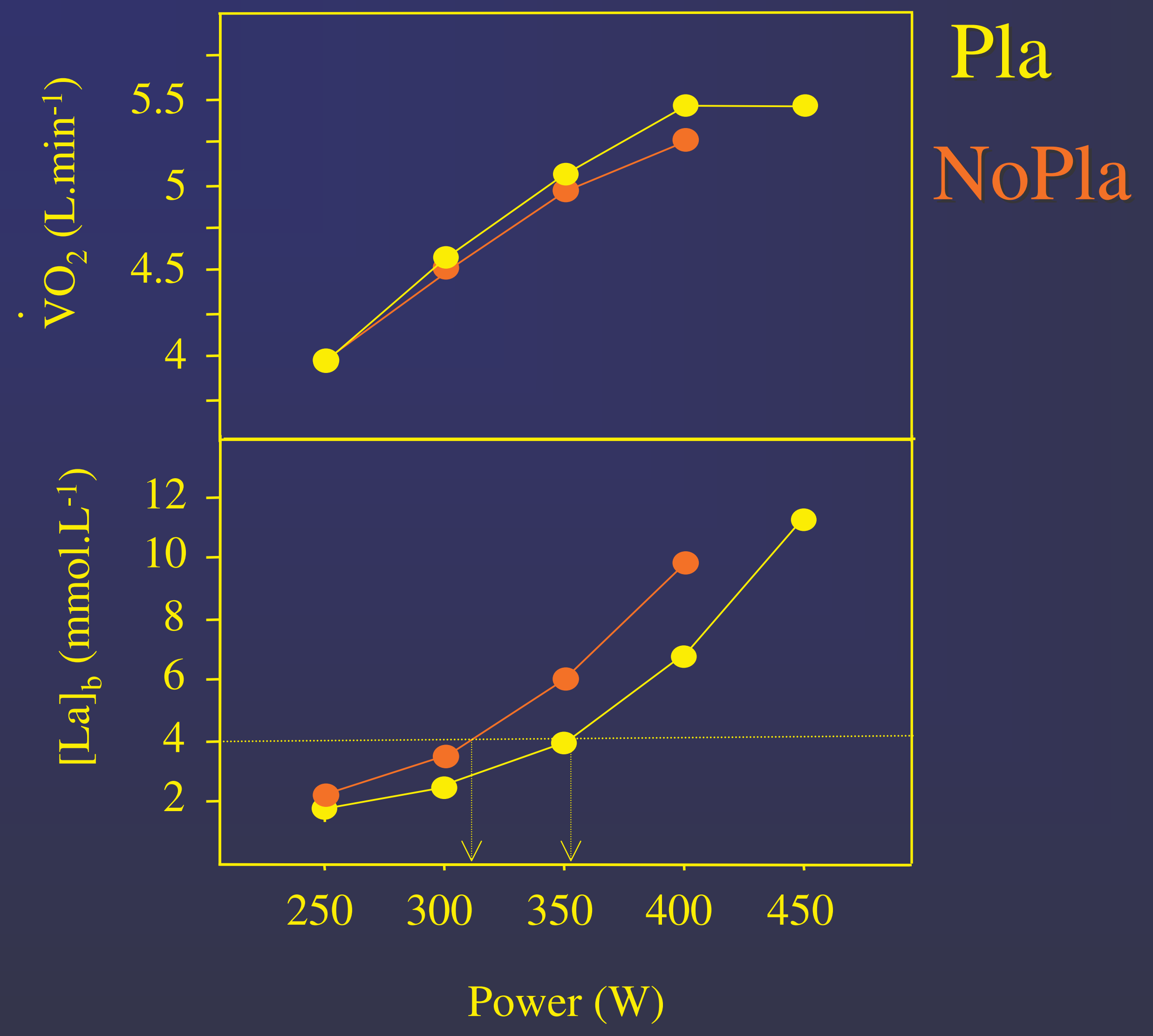
$\dot{V}O_2La4$ of rowers is significantly related to the ability to eliminate lactate from blood

(Messonnier et al. 1997)

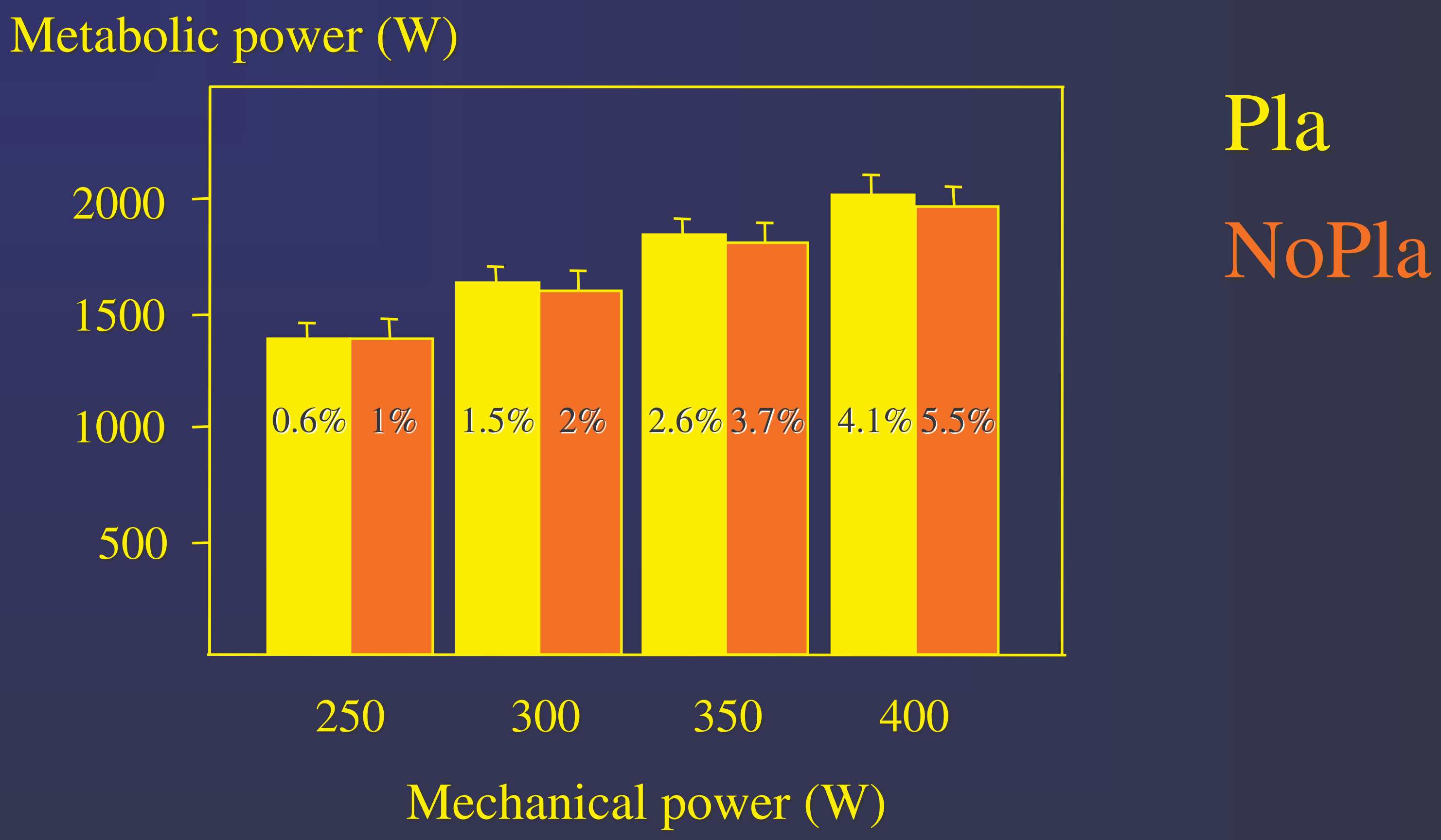
Lacour et al (2007)



	Pla	NoPla
Ppeak (%MAP)	113.7±3.9	106.3±4.5
Ergo Perf (s)	369.7±12.9	378.3±14



Pla
NoPla
$\dot{V}O_2$ (L.min-1)
5.5
5
4.5
4
$[La]_b$ (mmol.L-1)
12
10
8
6
4
2
250
300
350
400
450
Power (W)



Metabolic power (W)
2000
1500
1000
500
0.6%
1%
1.5%
2%
2.6%
3.7%
4.1%
5.5%
250
300
350
400
Mechanical power (W)
Pla
NoPla

	Pla	NoPla
$[La]_b$ peak ($mmol.l^{-1}$)	13±2.3	11.9±2.3

Conclusions

- Elimination improvement AND decrease in lactate production could explain increase in $\dot{V}O_2La4$.

- Pla and NoPla rowers demonstrate similar MAP and training experience: the ability to improve $\dot{V}O_2La4$ depends on rowers…


International
$\dot{V}O_2$ max
$\dot{V}O_2$ La4
O_2 consumption ($l.min^{-1}$)
18 yrs
6
5
4
3
2
1999
2000
2001
2002
2003
2004
2005
2006

Genetic characteristic or bias?

↓

Volume and intensity training load quantification

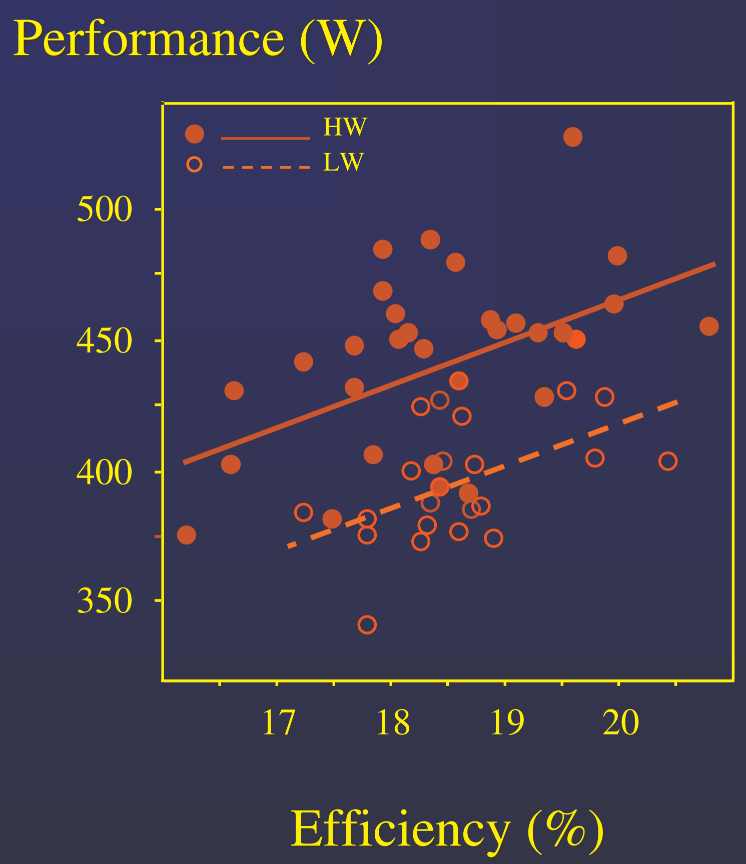
In perspective…

- Accurate quantification of JC Rolland training load to analyse variations in physiological ability with detraining

- Anaerobic capacity and muscular characteristic of rowers

Rowing efficiency

Efficiency = mechanical power/metabolic power



On-water rowing efficiency?

Thanks for your attention!