University of Ljubljana
October 2, 2017

High Performance in Olympic Sports

- physiological perspectives

H-C Holmberg

40-30-15


VÄLKOMMEN TILL NATIONELLT
VINTERSPORTCENTRUM
Nationellt
Vintersport
centrum
Mittuniversitetet
SVERIGE
CAMPUS
ÖSTERSUND
CRAFT
QUALISYS
DJO
GLOBAL
SKI GO
poc
SICS
PROMAS


Tromsö


Vancouver


Scandinavia
Microsoft MapPoint
Barents Sea
Norwegian Sea
ARCTIC OCEAN
Arctic circle
Arctic Circle
SCANDINAVIA
NORWAY
SWEDEN
FINLAND
RUSSIA
KARELIA
Northwest Federal District
MURMANSK
ATLANTIC OCEAN
North Sea
U.K.
DENMARK
ESTONIA
LATVIA
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BELARUS
TVER'
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Tromsø
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Leikanger
Lillehammer
Bergen
Gävle
Tampere
Vyborg
Cherepovets
Turku
Helsinki
St. Petersburg
Oslo
Uppsala
Tallinn
Novgorod
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Tønsberg
Stockholm
Örebro
Arendal
Kuressaare
Pskov
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Pärnu
Edinburgh
Göteborg
Linköping
Ålborg
Jönköping
Jēkabpils
Preili
Velikiye Luki
Carlisle
Ringkøbing
Århus
Växjö
Šiauliai
Panevėžys
Vitsyebsk
Karlskrona
Copenhagen
Sheffield
Flensburg
Mahilyow
Nykøbing
Słupsk
Gdynia
Vilnius
Minsk
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ÖSTERSUND
2019
IBU WORLD CHAMPIONSHIPS BIATHLON
Östersund
Mid Sweden University

Östersund FC

versus

Galatasaray
Fola Esch
Bilbao
Hertha Berlin
Zorja Luhansk

Swedish Winter Sports Research Centre

35 employees (**12** researchers)
Budget: 2-2.5 million $/yr
30-35 publications/yr


WORLD
LEADING
WORLD CLASS
HIGH PERFORMANCE


Melting Pot
Athletes Coaches Translators Researchers Students

Training
(STRUCTURE)

Practice isn't the thing you do once you're good. It's the thing you do that makes you good.

~Malcolm Gladwell

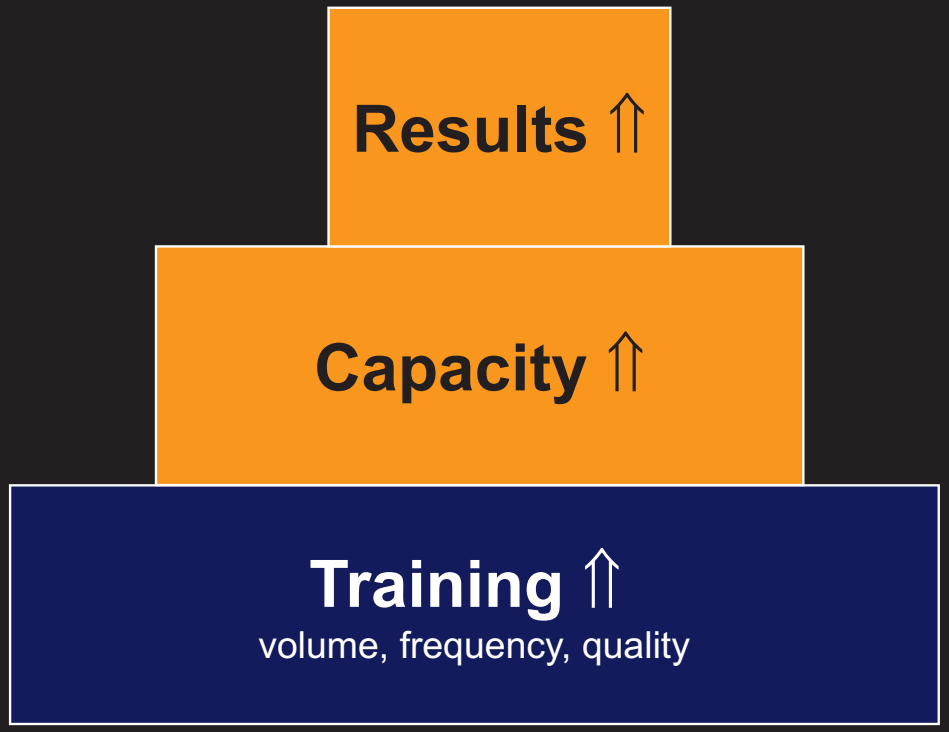

WORLD
LEADING
WORLD CLASS
HIGH PERFORMANCE

Träning

Video
SWE National Team
XC Skiing
TRAINING

TRAIN MORE ?

TRAIN SMARTER



Talent development

Olympic Athletes

- 600-1200 h/yr
- (8) 10-12 training sessions/week
- >48 training weeks/yr
- 20-100 competitions/yr

International Journal of Sports Physiology and Performance, 2014, 9, 117-121
http://dx.doi.org/10.1123/IJSPP.2013-0373

INTERNATIONAL JOURNAL OF
SPORTS PHYSIOLOGY
AND PERFORMANCE
www.IJSPP-Journal.com
INVITED COMMENTARY

A Reappraisal of Success Factors for Olympic Cross-Country Skiing

Øyvind Sandbakk and Hans-Christer Holmberg

TRAINING

750-950 h (60% May-Oct; 40% Nov-April)

670-830 h Endurance training (~10% at altitude >1500 m)
60-75% of Endurance training is skiing/roller skiing

Exercise intensity during **endurance** training

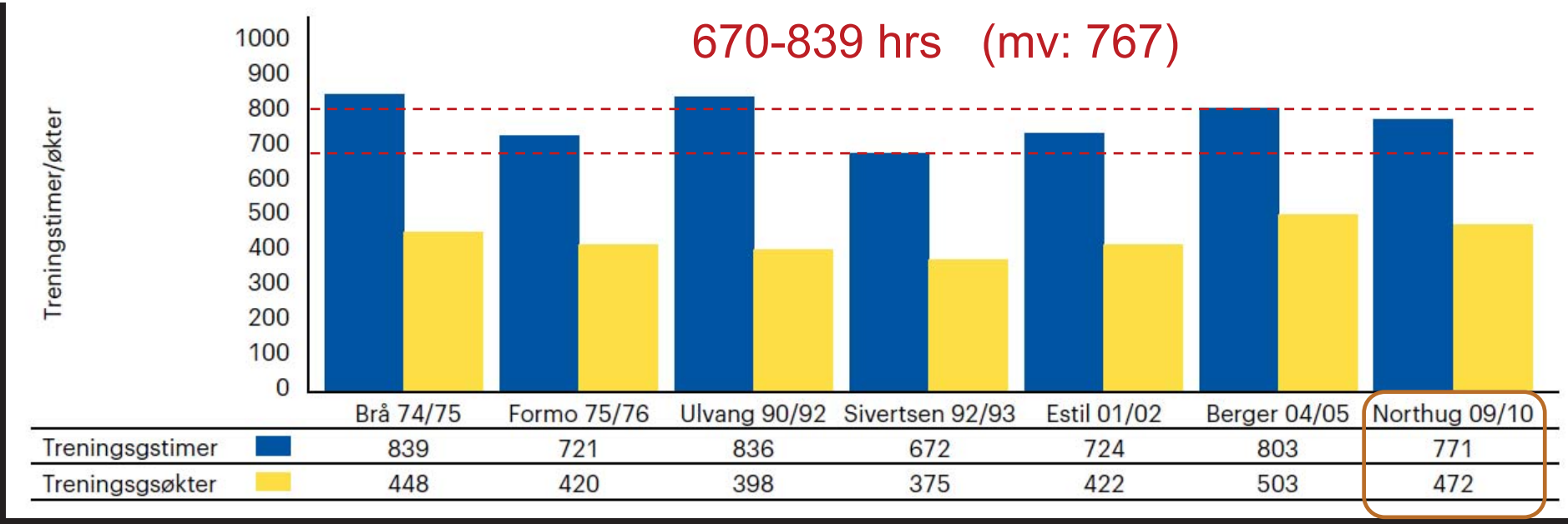
- High-intensity (>87% HR): **6-8%**
- Medium-intensity (80-87% HR): **4-6%**
- Low-intensity (60-80% HR): **86-89%**

75-100 h Strength & Power
15-20 h Specific speed training

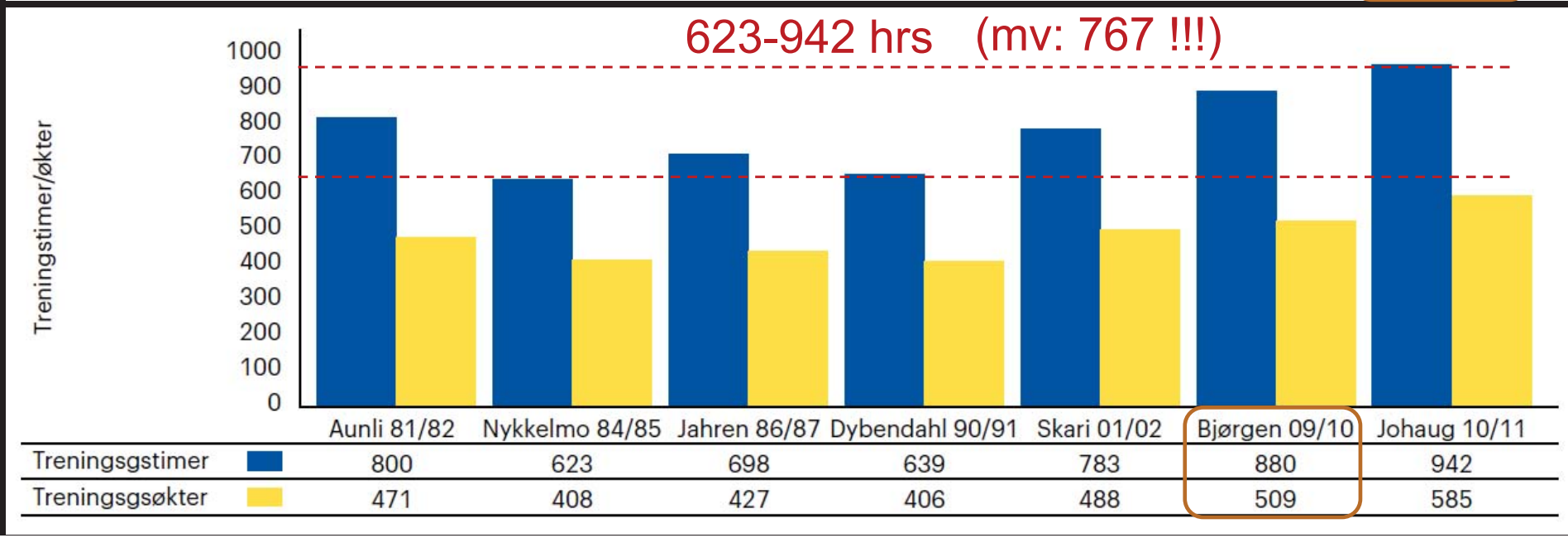
COMPETITIONS

48-62

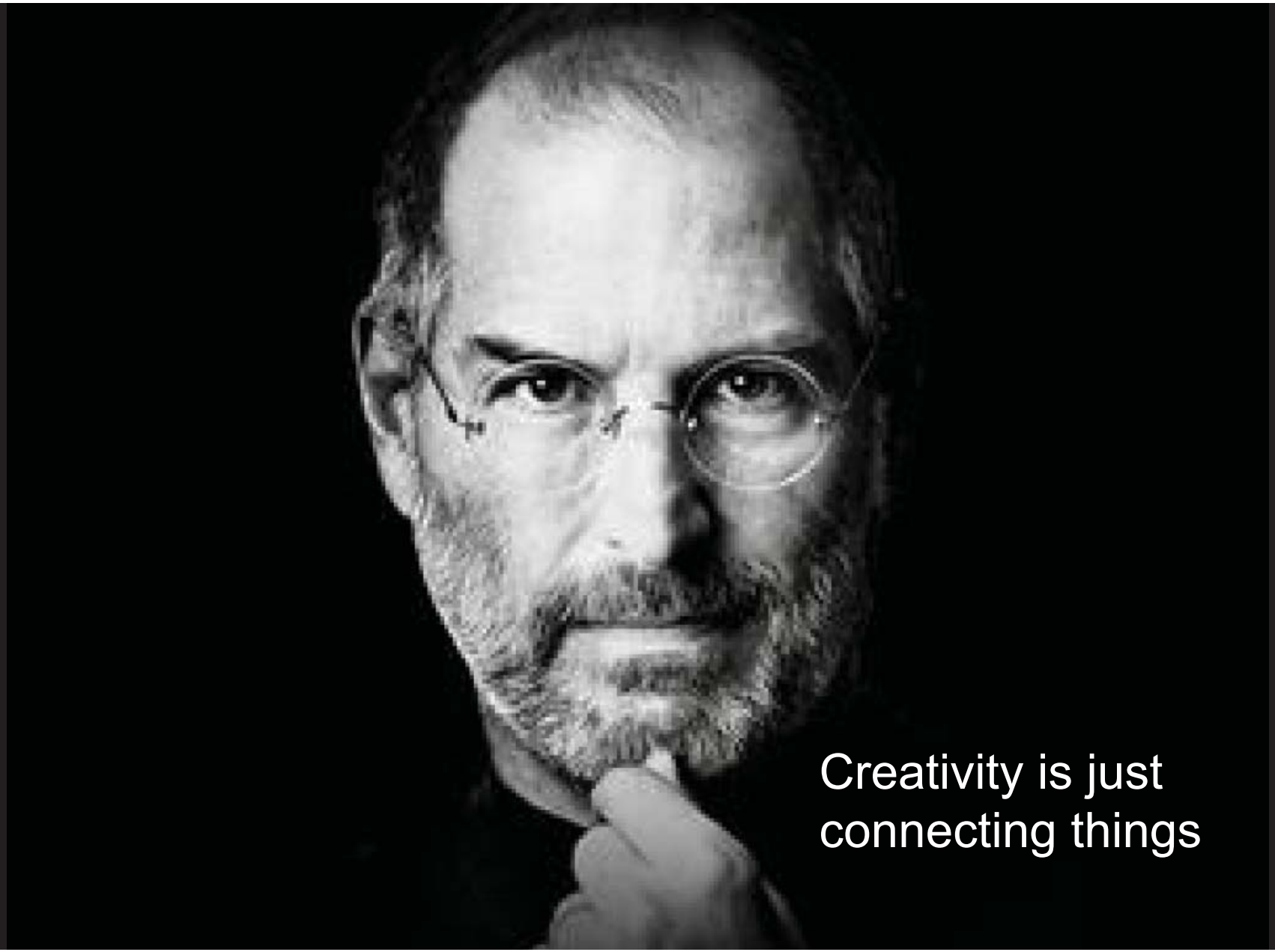
Nov-April: **35-44**
May-Oct (running, roller-skis): **10-20**

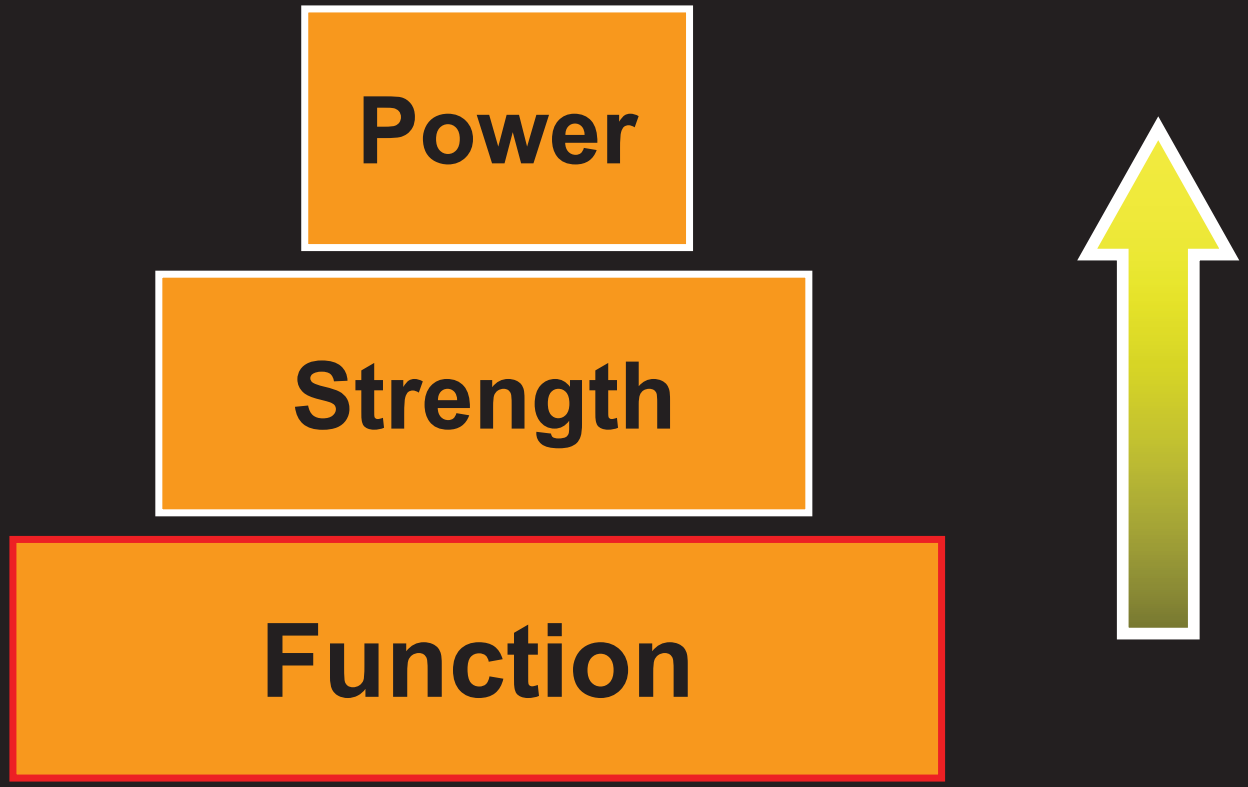


	Brå 74/75	Formo 75/76	Ulvang 90/92	Sivertsen 92/93	Estil 01/02	Berger 04/05	Northug 09/10
Treningsgstimer	839	721	836	672	724	803	771
Treningsgsøkter	448	420	398	375	422	503	472



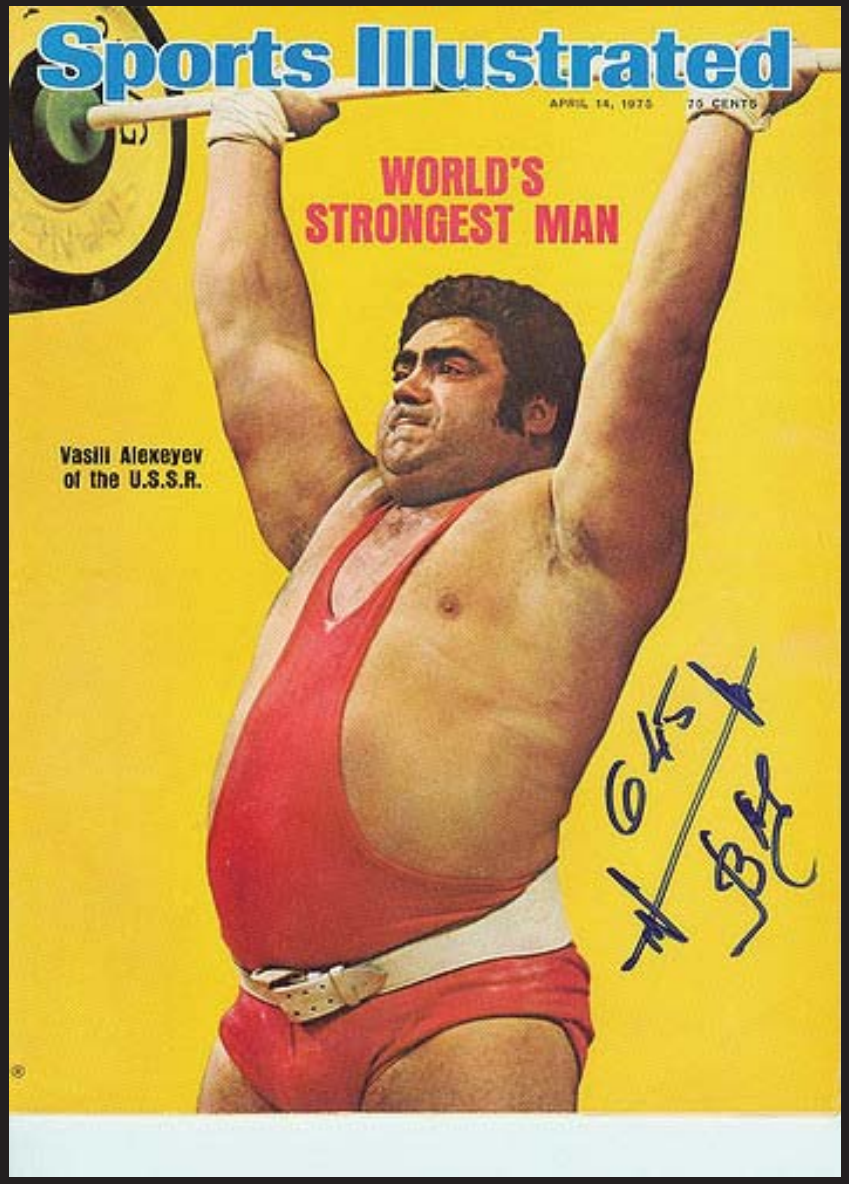
	Aunli 81/82	Nykkelmo 84/85	Jahren 86/87	Dybendahl 90/91	Skari 01/02	Bjørgen 09/10	Johaug 10/11
Treningsgstimer	800	623	698	639	783	880	942
Treningsgsøkter	471	408	427	406	488	509	585


Creativity is just
connecting things


Power
Strength
Function

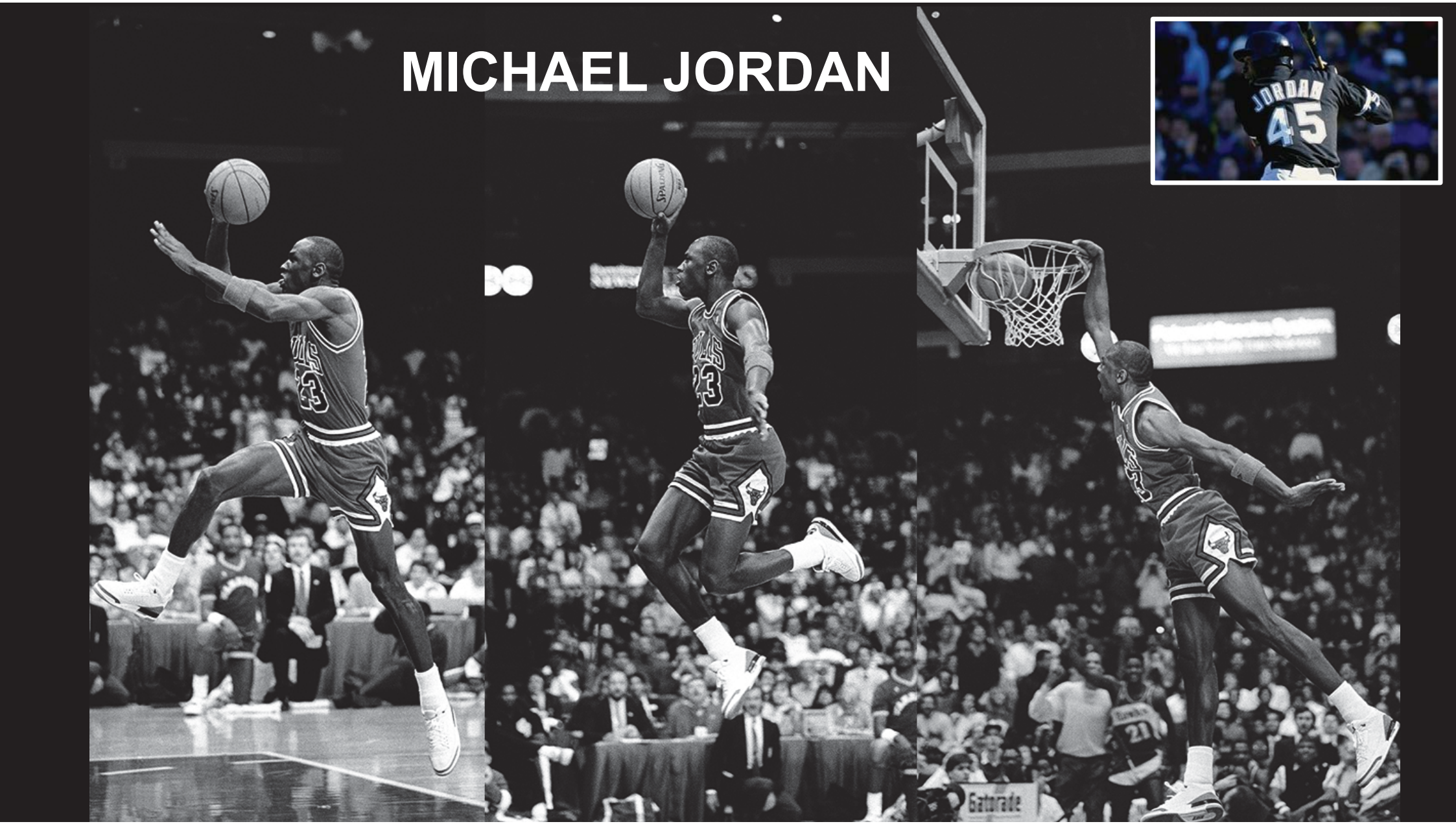
Athleticism

The ***Discobolus*** *of Myron*
460–450 BC


Sports Illustrated
APRIL 14, 1975 75 CENTS
WORLD'S STRONGEST MAN
Vasili Alexeyev of the U.S.S.R.


ELAN
RACING

MICHAEL JORDAN



Strength

Power

Speed

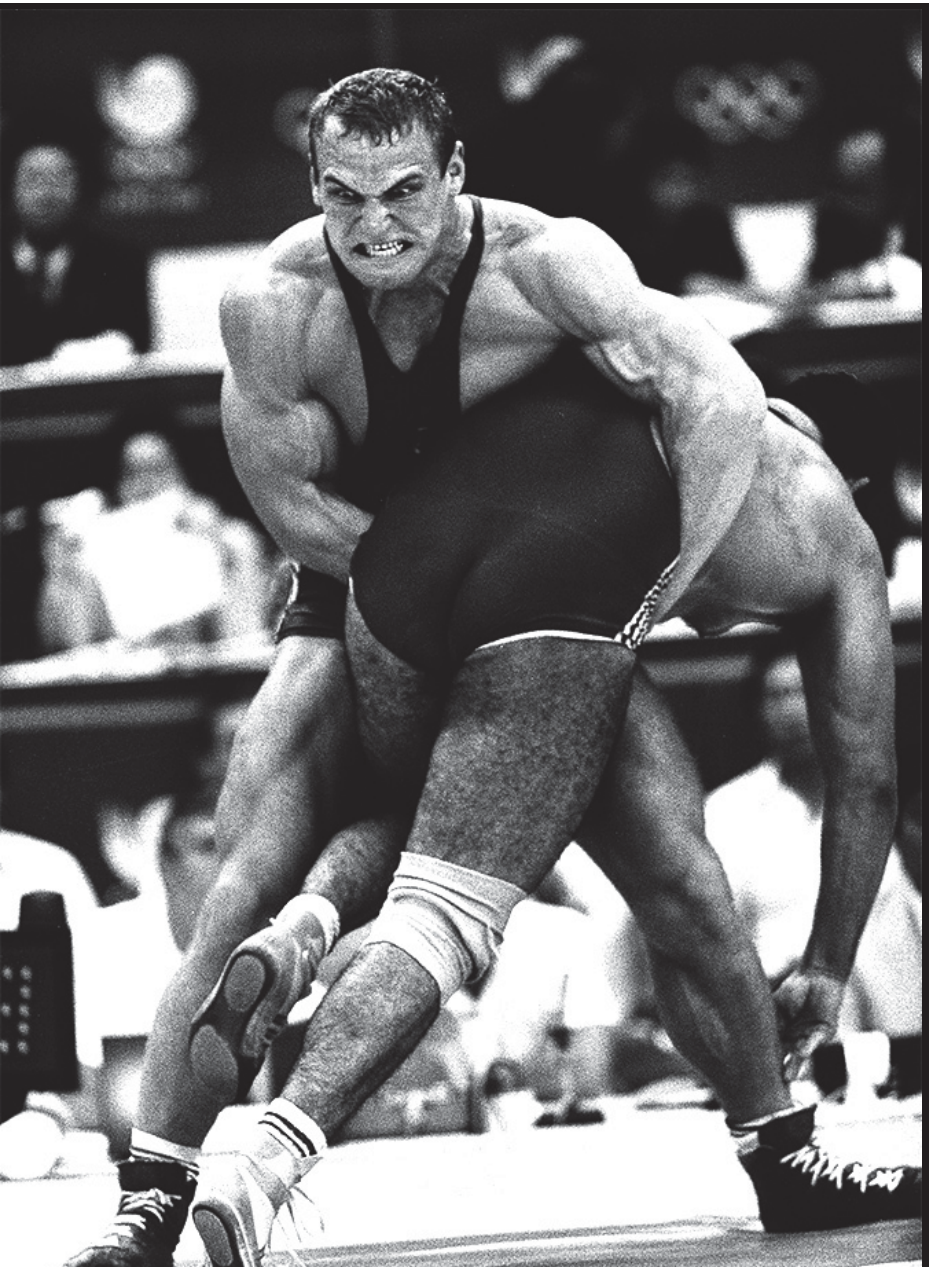
STRENGTH

XC Skiing

Soccer

Tennis

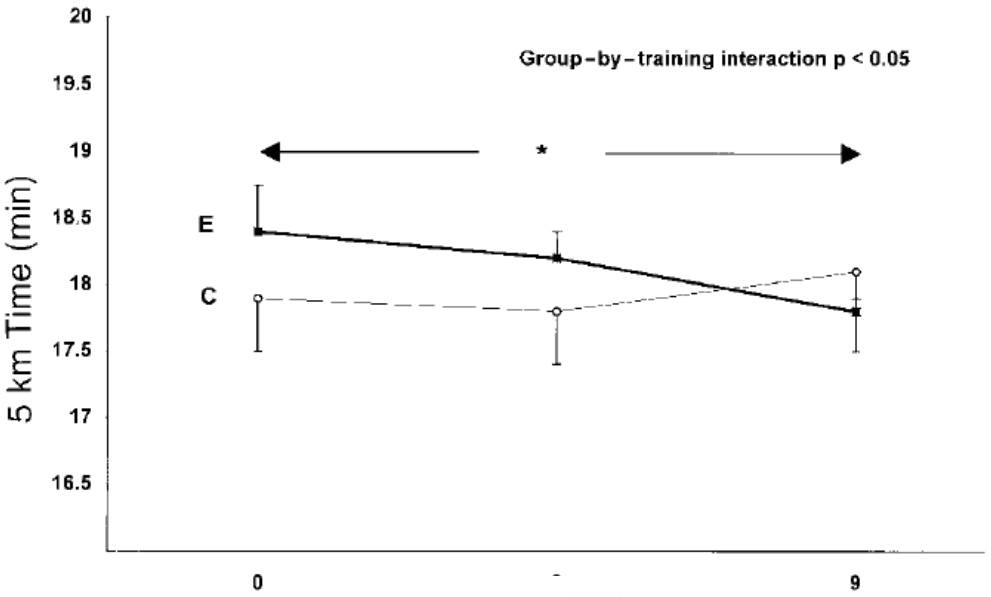
1-3 (4) x /wk




SWEDEN
TDK
STÅHL
LONDON 2017

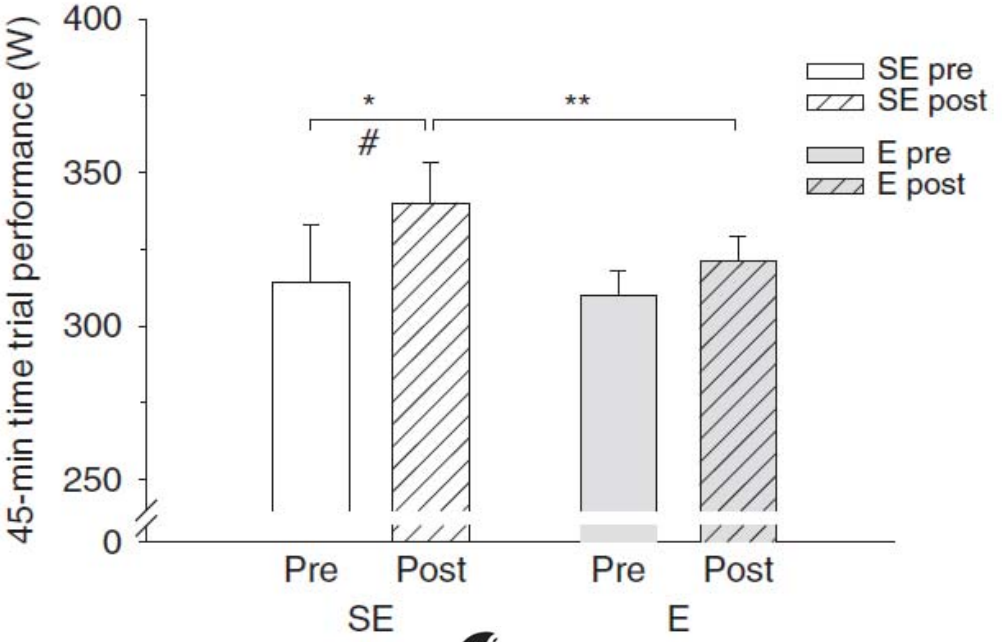

USA
ELEIKO
HOUSTON
2015

PERFORMANCE



PLYO + EXPLO

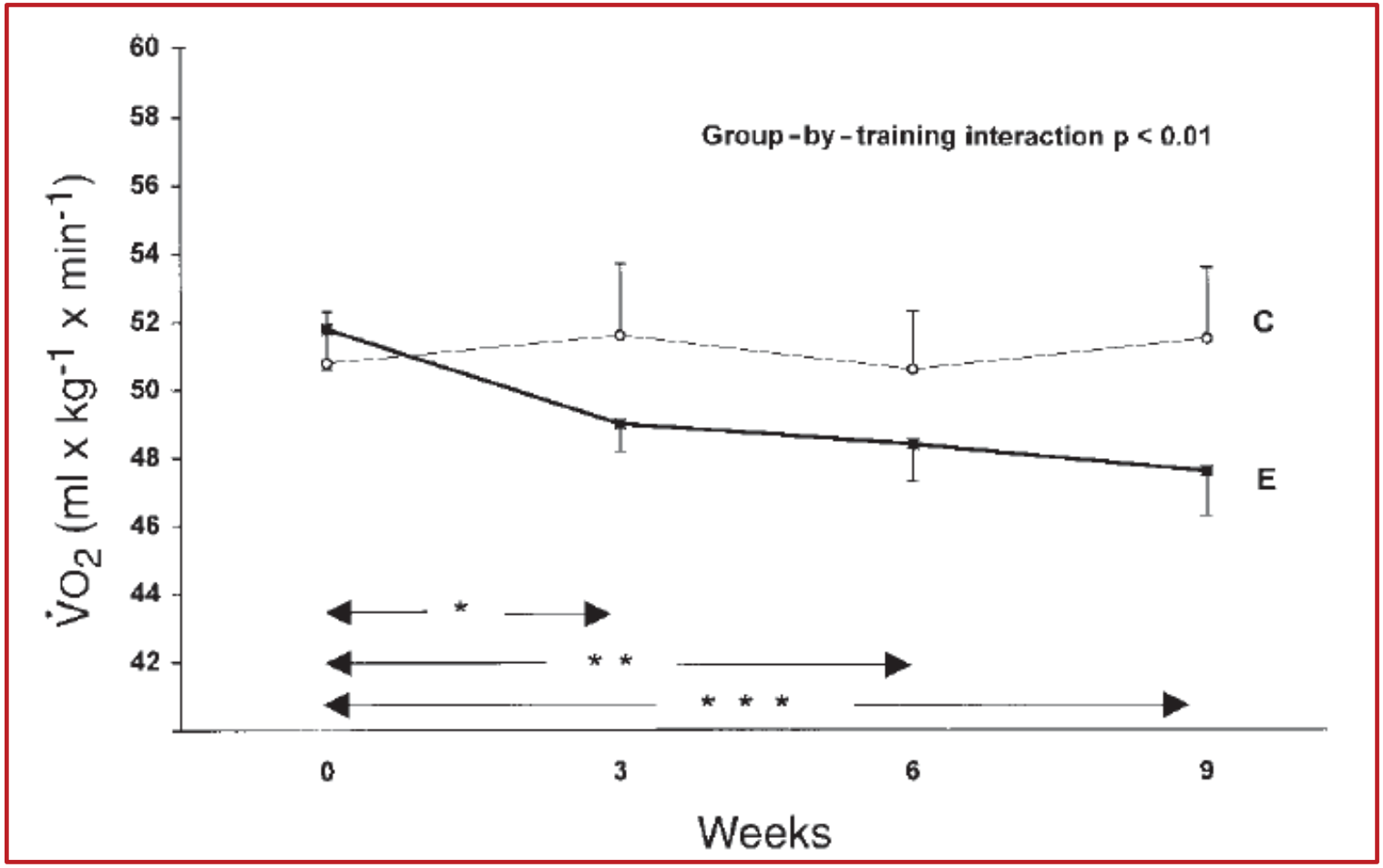
5,000 m TT



5-6 REPS

45 min TT

WORK ECONOMY



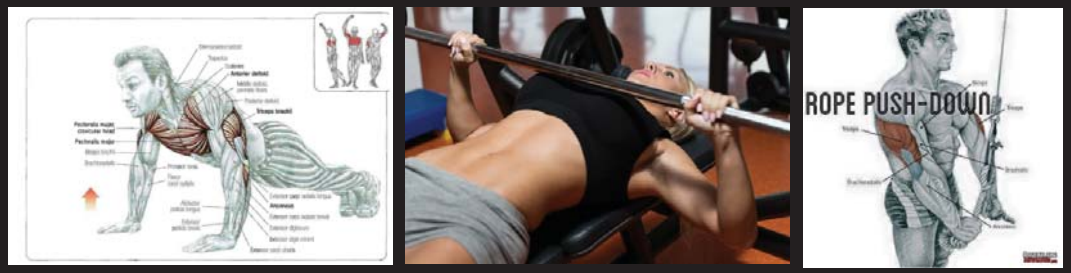
POSITIVE EFFECT **(most studies)**


© H.-C. HOLMBERG
Base level
General strength
Specific strength
General strength - ”tool” to develop specific strength

BASIC

Leg-trunk

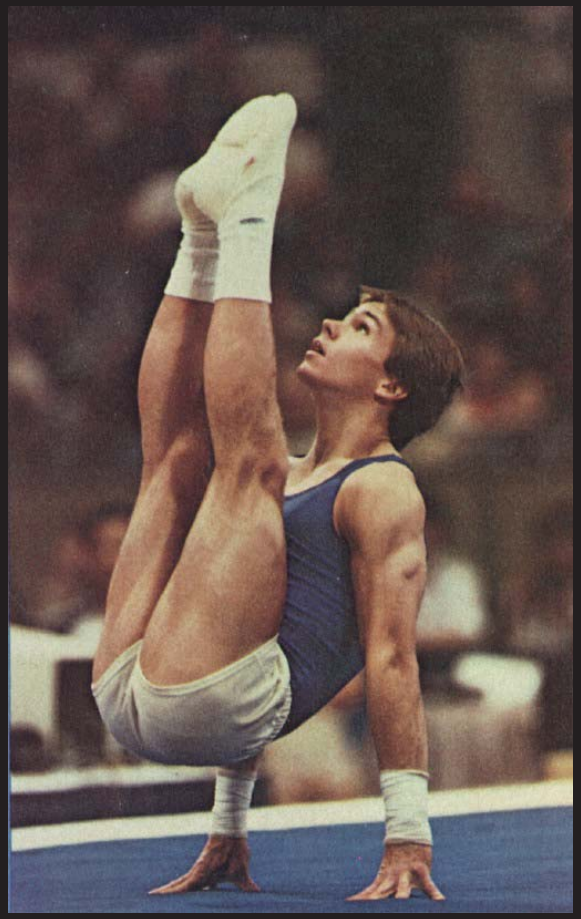
Pull



Push

CORE

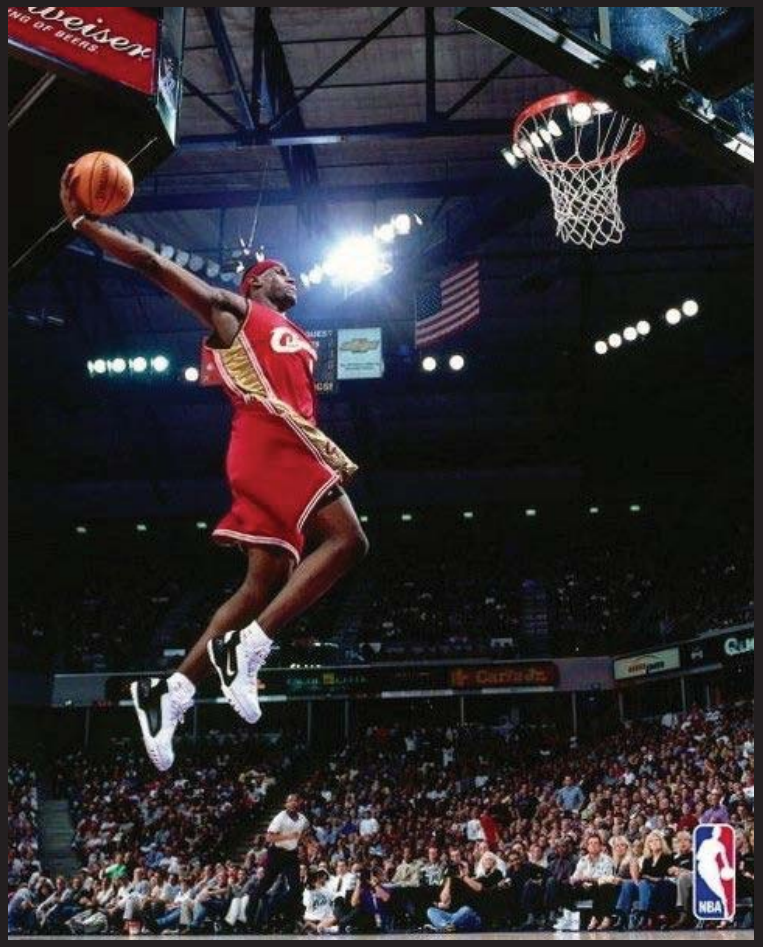
Elastic (jump)



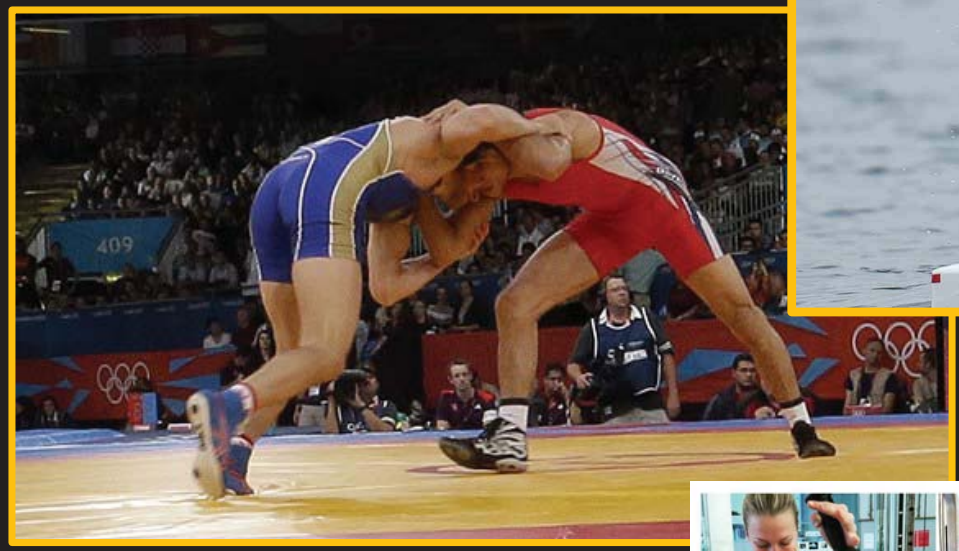
Stability
Mobility
Strength

Muscle balance

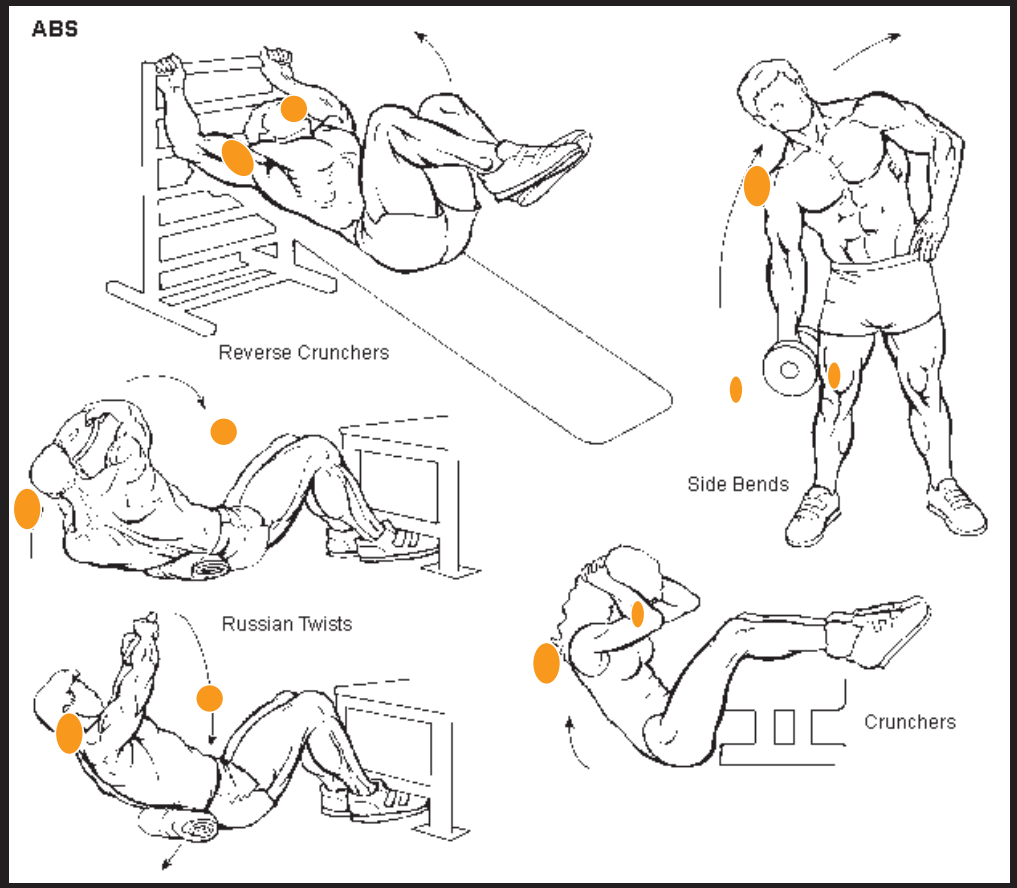
ANT vs POST
LEFT vs RIGHT
Upper vs Lower body

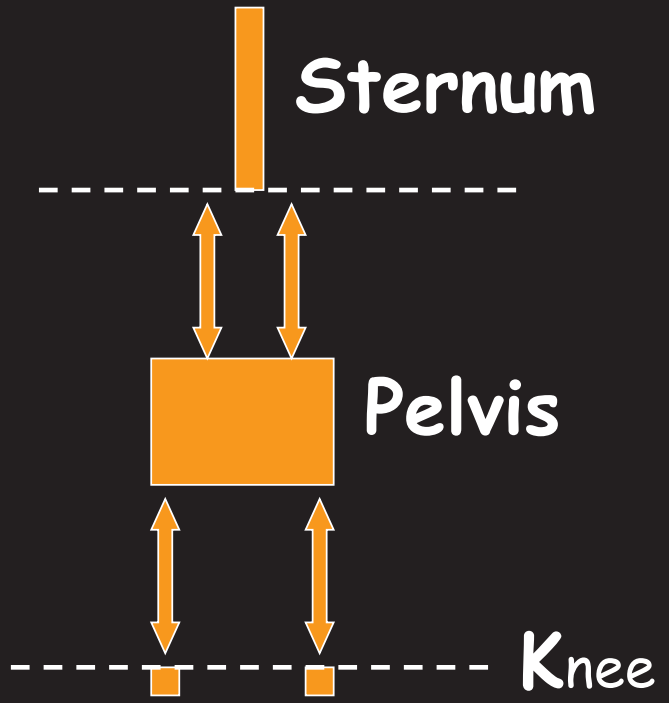


UPPER BODY

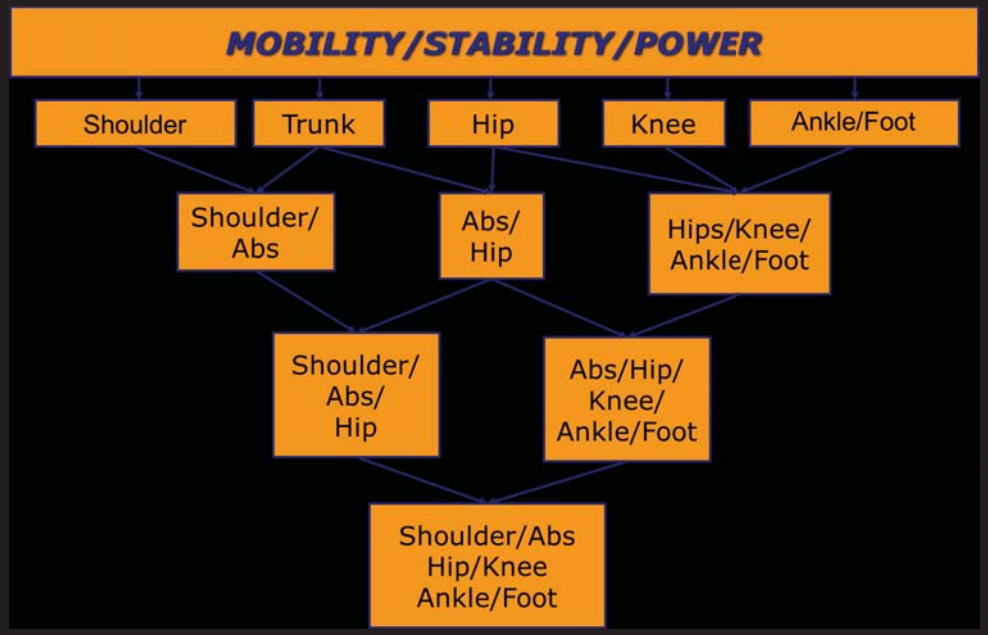


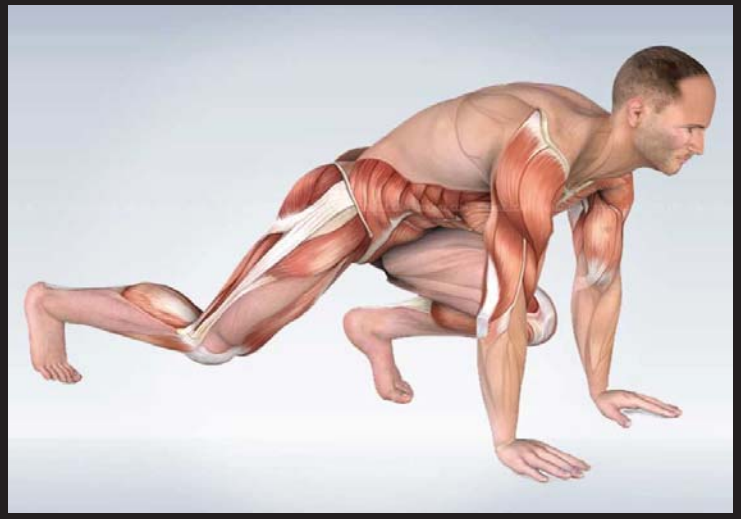
"Core Strength"





SPK-strength


MOBILITY/STABILITY/POWER
Shoulder
Trunk
Hip
Knee
Ankle/Foot
Shoulder/
Abs
Abs/
Hip
Hips/Knee/
Ankle/Foot
Shoulder/
Abs/
Hip
Abs/Hip/
Knee/
Ankle/Foot
Shoulder/Abs
Hip/Knee
Ankle/Foot




JAMAICA
BOLT
7

The Physiology of Two Champions

OG/WCh
4 Gold
7 Silver
3 Bronze

BW = 75 kg

BW = 59 kg

OG/WCh
4 Gold
7 Silver
3 Bronze

1RM

Bench press:	85 kg	(1.1xBW)
Bench pull:	75 kg	(1.0xBW)
Power clean:	90 kg	(1.2xBW)
Back squats:	130 kg	(1.7xBW)

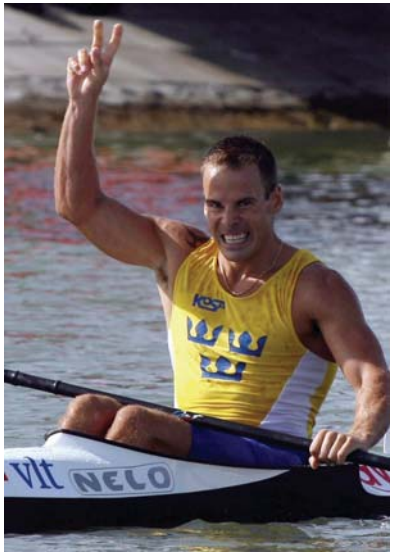
Bench press:	60 kg	(1.0xBW)
Bench pull:	55 kg	(0.9xBW)
Power clean:	57.5 kg	(1.0xBW)
Back squats:	92.5 kg	(1.6xBW)

The Physiology of Two Champions

OG/WCh
4 Gold
7 Silver
3 Bronze

BW = 75 kg

1RM



BW = 82 kg

OG/WCh
4 Gold
2 Silver
1 Bronze

Bench press:	85 kg	(1.1xBW)
Bench pull:	75 kg	(1.0xBW)
Power clean:	90 kg	(1.2xBW)
Back squats:	130 kg	(1.7xBW)

Bench press:	135 kg	(1.6xBW)
Bench pull:	120 kg	(1.4xBW)
Power clean:	95 kg	(1.2xBW)
Back squats:	100 kg	(1.2xBW)

The Physiology of Two Champions

200-m Kayaker

OG/WCh
4 Gold
2 Silver
1 Bronze

1RM

BW = 82 kg

Bench press:	(1.9xBW)	135 kg (1.6xBW)
Bench pull:	(1.6xBW)	120 kg (1.4xBW)
Power clean:	(1.4xBW)	95 kg (1.2xBW)
Back squats:	(1.8xBW)	100 kg (1.2xBW)

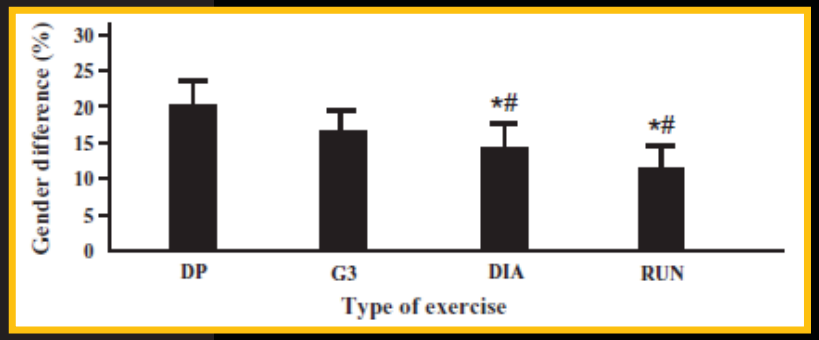
200 m: ~30s

500 m – 1000 m
1.35-3.30 (4.00) min

Marit Björgen

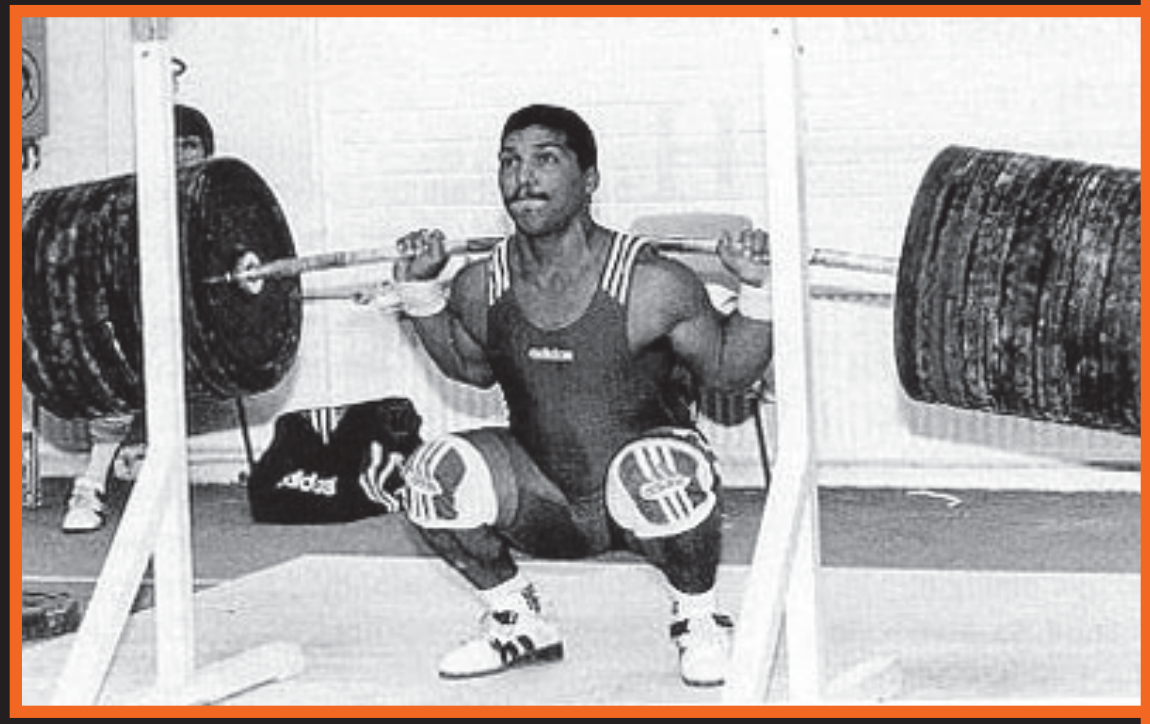
36 medals

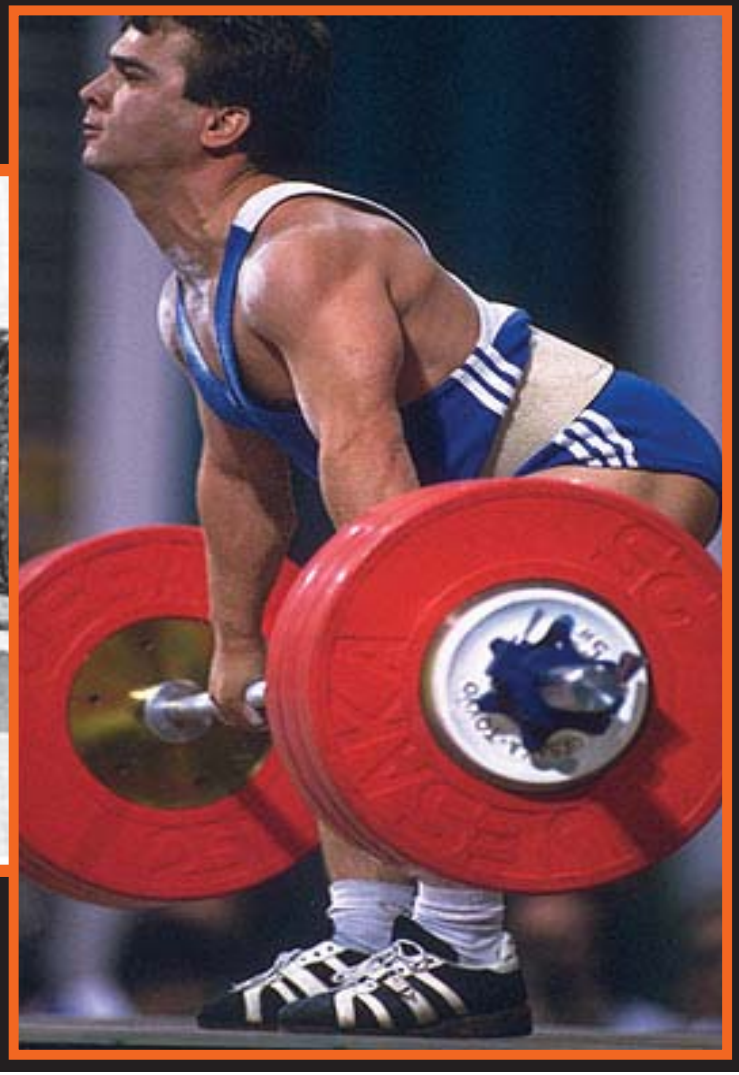
Olympic Games/World Championships



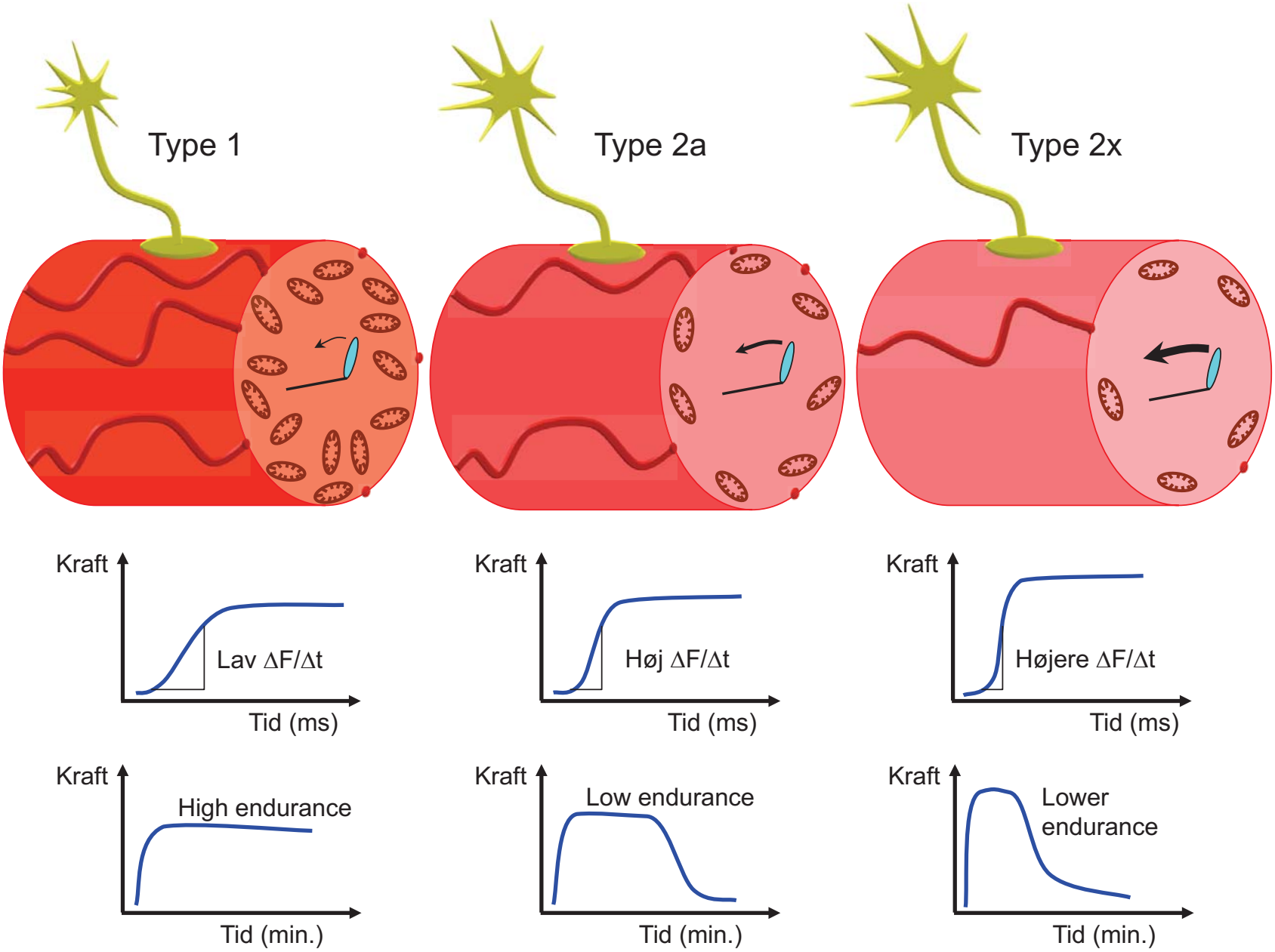
Important distinction

Power



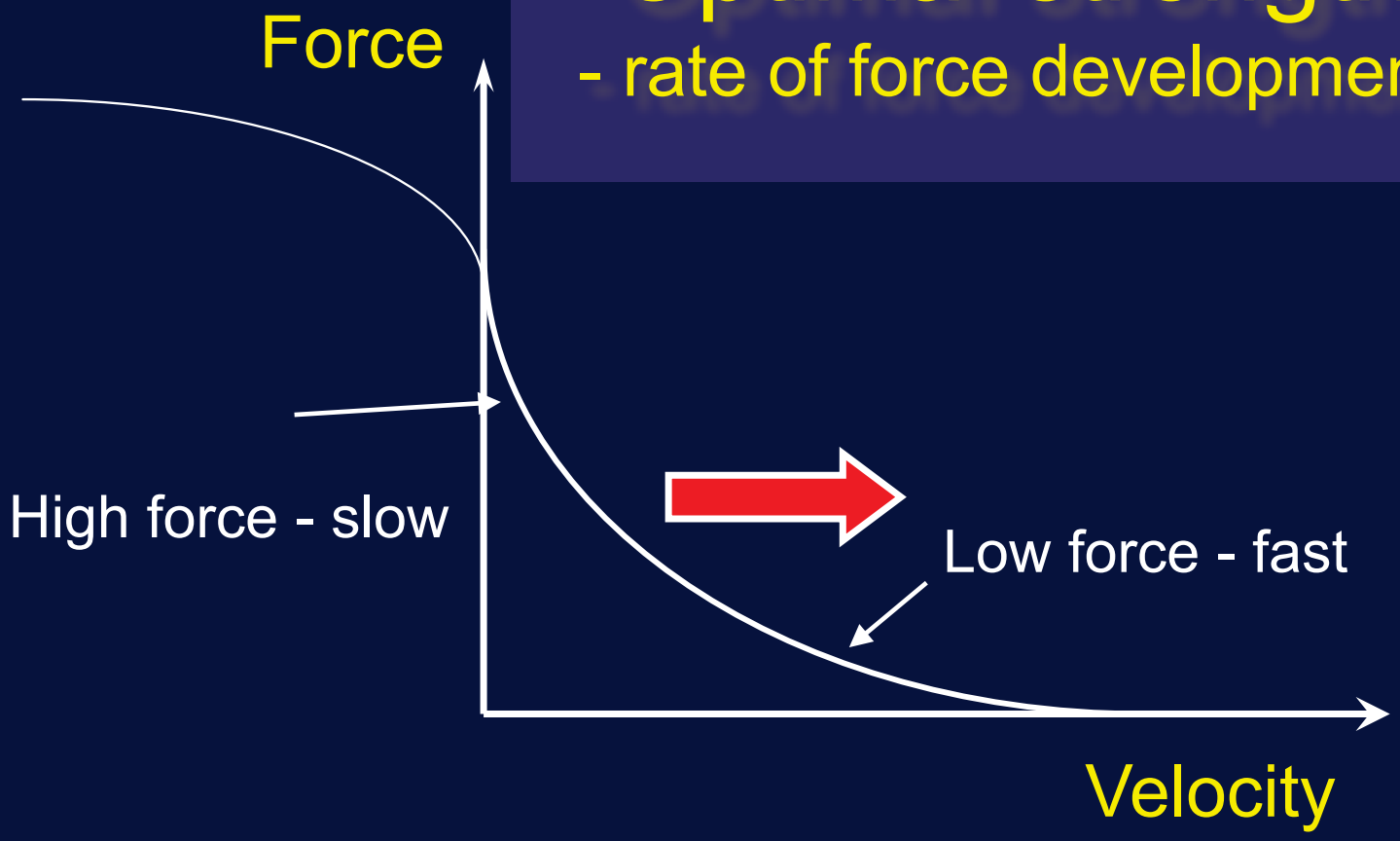


Strength


Type 1
Type 2a
Type 2x
Kraft
Lav ΔF/Δt
Tid (ms)
Kraft
Høj ΔF/Δt
Tid (ms)
Kraft
Højere ΔF/Δt
Tid (ms)
Kraft
High endurance
Tid (min.)
Kraft
Low endurance
Tid (min.)
Kraft
Lower endurance
Tid (min.)

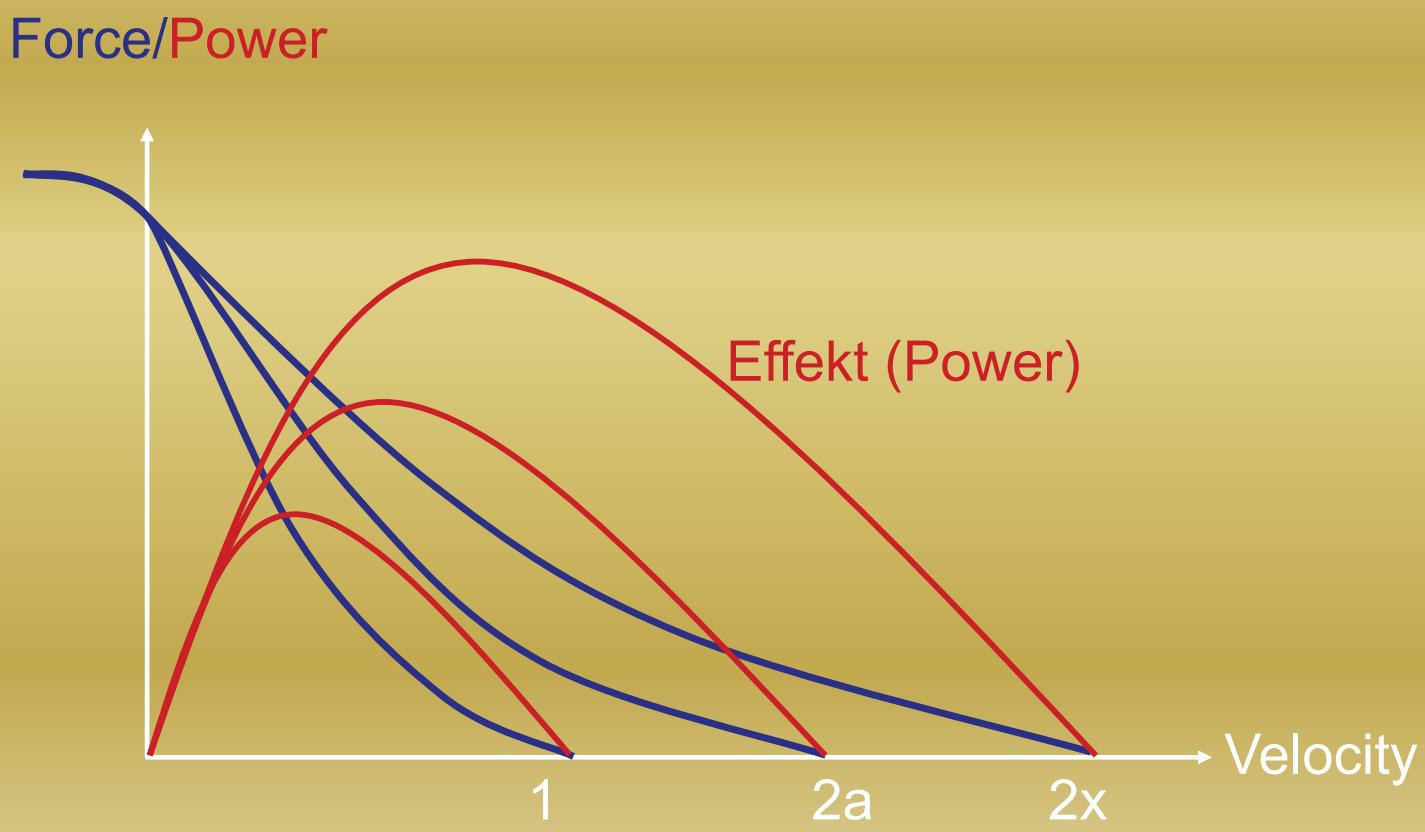
”Optimal strength”

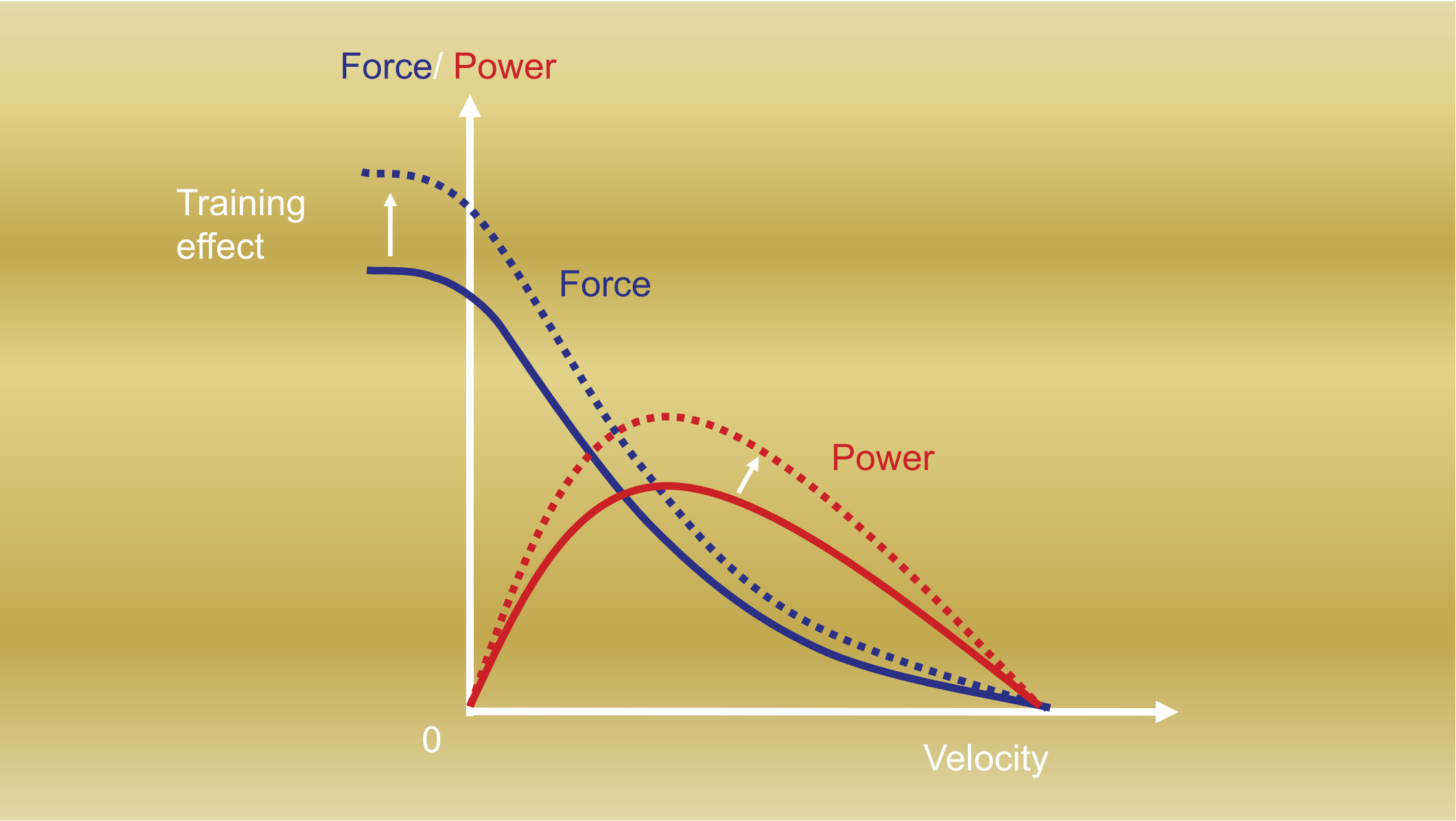
- rate of force development



”the ability to develop force fast is more important than than maximal force”

H.-C. HOLMBERG


Force/Power
Effekt (Power)
Velocity
1
2a
2x


Force/ Power
Training
effect
Force
Power
0
Velocity

TRANSFER

ATHLETIC EXCELLENCE

Ability to maintain ...

TECHNICAL excellence

at **SPEED**

under **PRESSURE**

when **FATIGUED**

Goldsmith, 2003

Peak power output: >1100 W (10 s)
360-400 W (1-min)

Very good at 5000 m
Slow start (fibre composition, power, technique

REVIEW ARTICLE

Sports Med 2004; 34 (13): 891-927
0112-1642/04/0013-0891/$31.00/0

Physiological Changes Associated with the Pre-Event Taper in Athletes

Iñigo Mujika,[1,2] *Sabino Padilla*,[1] *David Pyne*[2] and *Thierry Busso*[3]

1 Department of Research and Development, Medical Services, Athletic Club of Bilbao, Basque Country, Spain
2 Department of Physiology, Australian Institute of Sport, Canberra, ACT, Australia
3 Research Group, Physiology and Physiopathology of Exercise and Handicap, University of Saint-Etienne, Saint-Etienne, France

It is notable that enhanced power is often described as an important benefit of tapering, whereas endurance training with high volumes often produces the opposite effect.

Table VI. Effects of the taper on muscular strength and power

Study (year)	Athletes	Taper duration (days)	Strength and/or power	Performance measure	Performance outcome (%)
Costill et al.[3] (1985)	Swimmers	14	↑	46–1509m competition	2.2–4.6 impr
Cavanaugh and Musch[2] (1989)	Swimmers	28	↑	46–1509m competition	2.0–3.8 impr
Prins et al.[122] (1991)	Swimmers	28	↔	NR	NR
Johns et al.[7] (1992)	Swimmers	10–14	↑	46–366m competition	2.0–3.7 impr
Shepley et al.[30] (1992)	Runners	7	↑	Treadmill time to exhaustion	6–22 impr
Gibala et al.[123] (1994)	Strength trained	10	↑	Voluntary elbow flexor strength	≈7 impr
Houmard et al.[35] (1994)	Runners	7	↔	5km treadmill time trial	2.8 impr
Martin et al.[124] (1994)	Cyclists	14	↑	Incremental maximal test	8.0 impr
Raglin et al.[14] (1996)	Swimmers	28–35	↑	Competition	2.0 impr
Hooper et al.[6] (1998)	Swimmers	14	↑	100m, 400m time trial	↔
Hooper et al.[49] (1999)	Swimmers	14	↔	100m time trial	↔
Trappe et al.[17] (2000)	Swimmers	21	↑	Competition	3.0–4.7 impr

impr = improvement; **NR** = not reported; ↑ indicates increased; ↔ indicates unchanged.

HI PERFORMANCE TRAINING

based on…

Experience

Knowledge

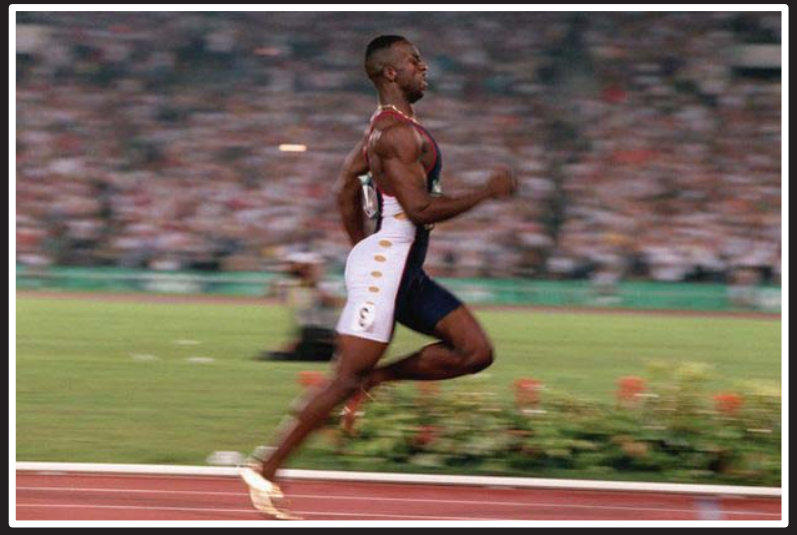
WHEN?

Positioning of Strength training in relation to Endurance training

1. Single workout
2. Strength + endurance – different muscles
3. Strength + endurance – same muscles
4. Endurance + Strength – different muscles
5. Endurance + Strength – same muscles

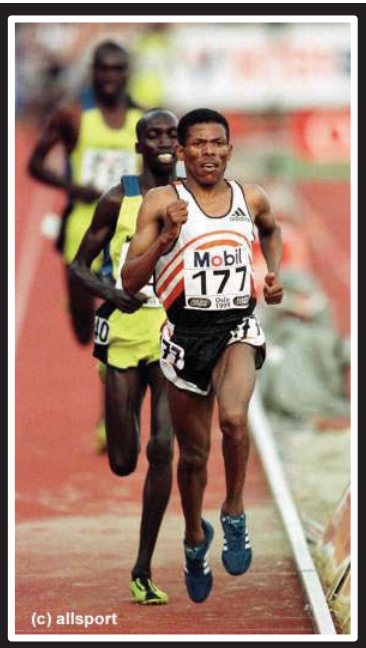
Endurance

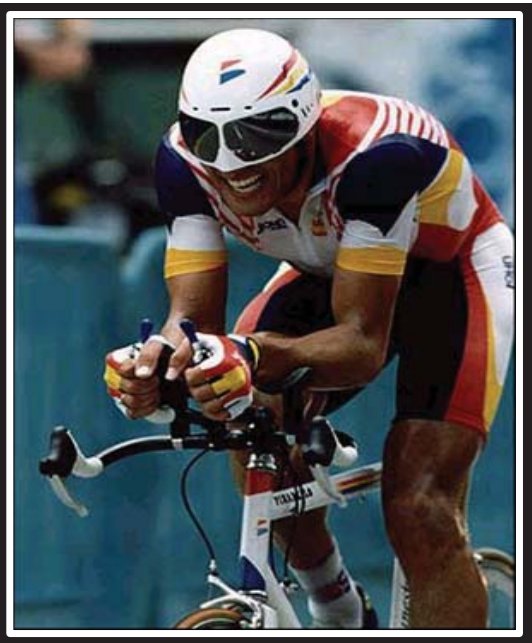
Racing time: 30 s to 1 min



Racing time: 1 to 6-7 min

Racing time: 25 min-~2 hrs





Important Factors for Performance

VO_2 max (peak)

Strength/Power

Fractional utilization of VO_2

Work economy/ efficiency

Fibre type/ characteristics

Technique

ENDURANCE

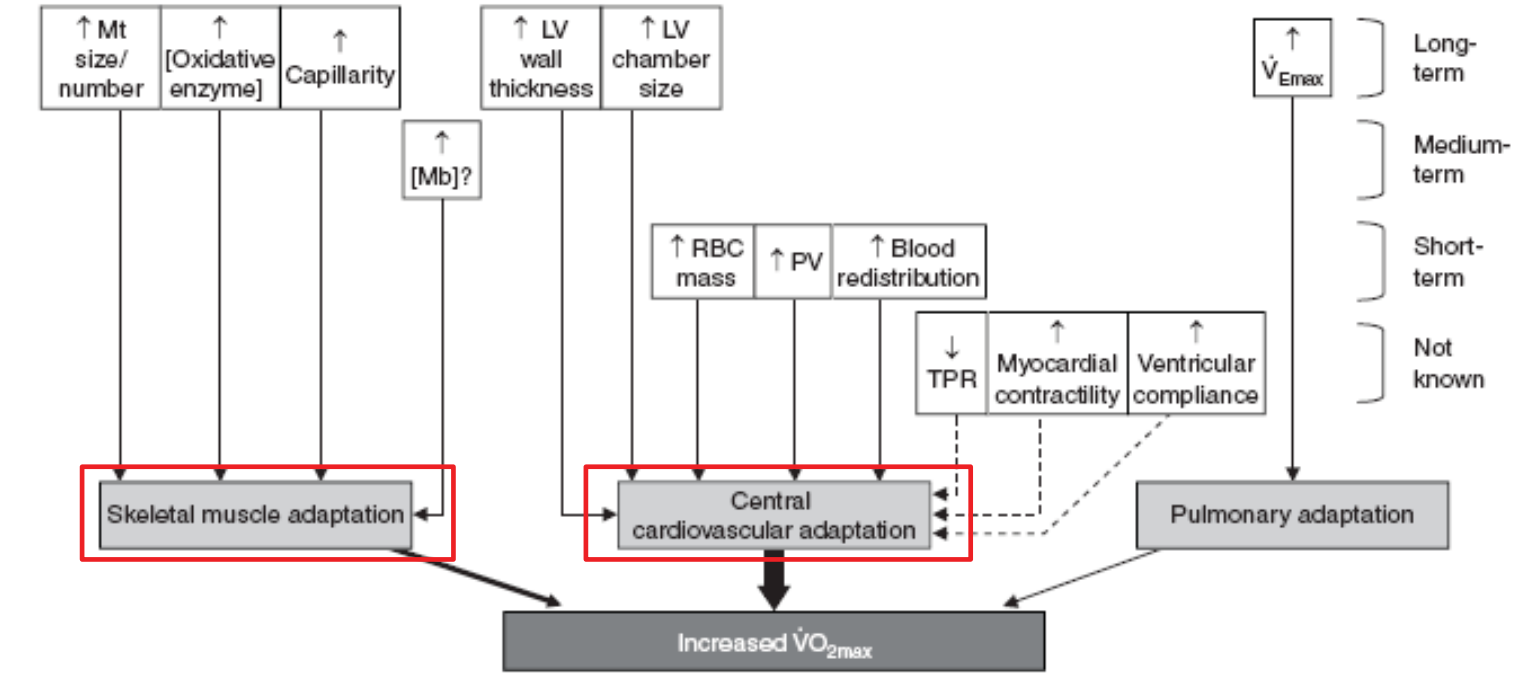


Fig. 1. Training-induced physiological adaptations associated with the enhancement of maximal oxygen uptake ($\dot{V}O_{2max}$). Short-, medium- and long-term adaptations typically have a maximum period of adaptability of days, months and years, respectively. The arrows with broken lines indicate the time course of those adaptations has presently not been elucidated. The width of the three shaded arrows at the bottom of the figure broadly represent the total contribution of those adaptations in the long-term enhancement of $\dot{V}O_{2max}$. Maximum period of adaptability for myoglobin concentration based on rat studies. **LV** = left ventricular; **[Mb]** = myoglobin concentration; **Mt** = mitochondrial; **[Oxidative enzyme]** = oxidative enzyme concentration; **PV** = plasma volume; **RBC** = red blood cell; **TPR** = total peripheral resistance; $\dot{V}_{Emax}$ = maximal minute ventilation; ↑ indicates increase; ↓ indicates decrease; **?** indicates presently unknown if training-induced increases occur in humans under normoxic conditions.

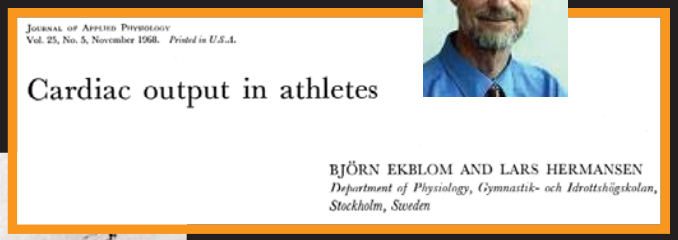
VO_2 max

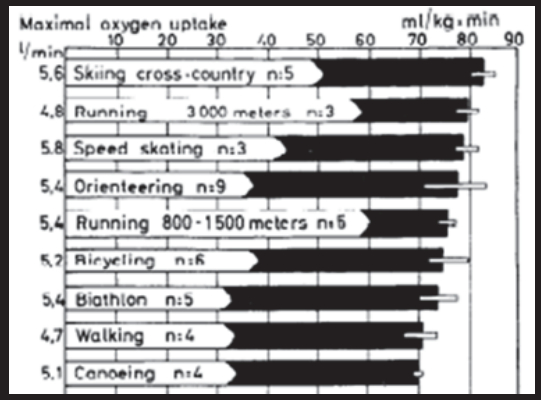
NATURE November 12, 1955 Vol. 176

New Records in Human Power

81.7 ml · kg^{-1} · min^{-1}
6.0 l · min^{-1}

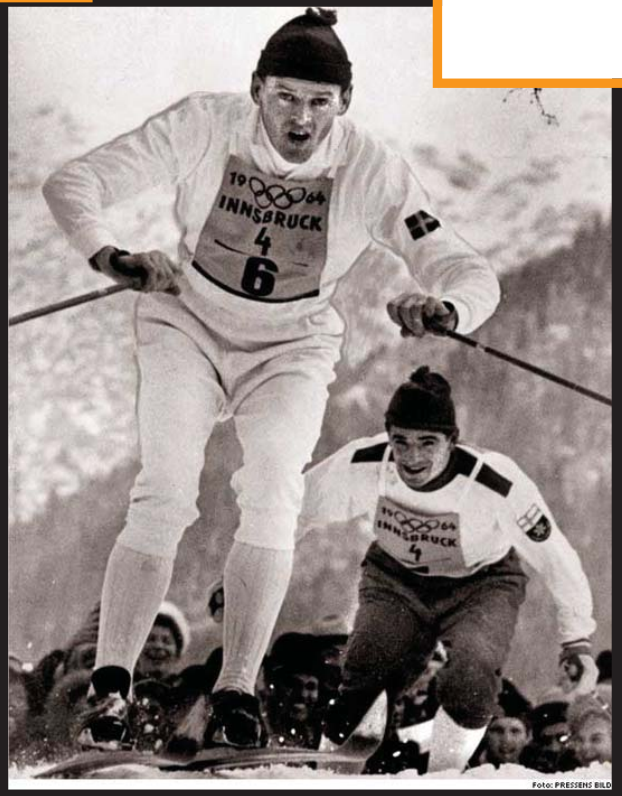
	Heart-rate	Pulmonary ventilation* (l./min.)	Oxygen intake (l./min.)† determined	Oxygen intake (l./min.)† estimated‡	Oxygen intake ml./kgm./min. † determined
Skiers					
♂ Jernberg, S.	179	146	5·88	6·1	81·7
♂ Larsson, L.	182	111	5·49	6·1	81·3
♂ Larsson, P. E.	190	119	5·38	5·6	80·3
♂ Samuelsson, G.	182	150	5·34	—	78·5
♂ Gunnarsson, S.	179	130	5·20	5·4	79·1
♀ Eriksson, A. L.	188	105	3·97	4·6	68·4





VO_2 max
5.6 L min^{-1}
(6.17 L min^{-1})

80 mL kg^{-1} min^{-1}



The value of 85.1 ml/kg is the highest reported so far…

Cardiac output
36 ± 4.7 L
(42.3 L)

Stroke volume
189 ± 18.8 mL
(212 mL)

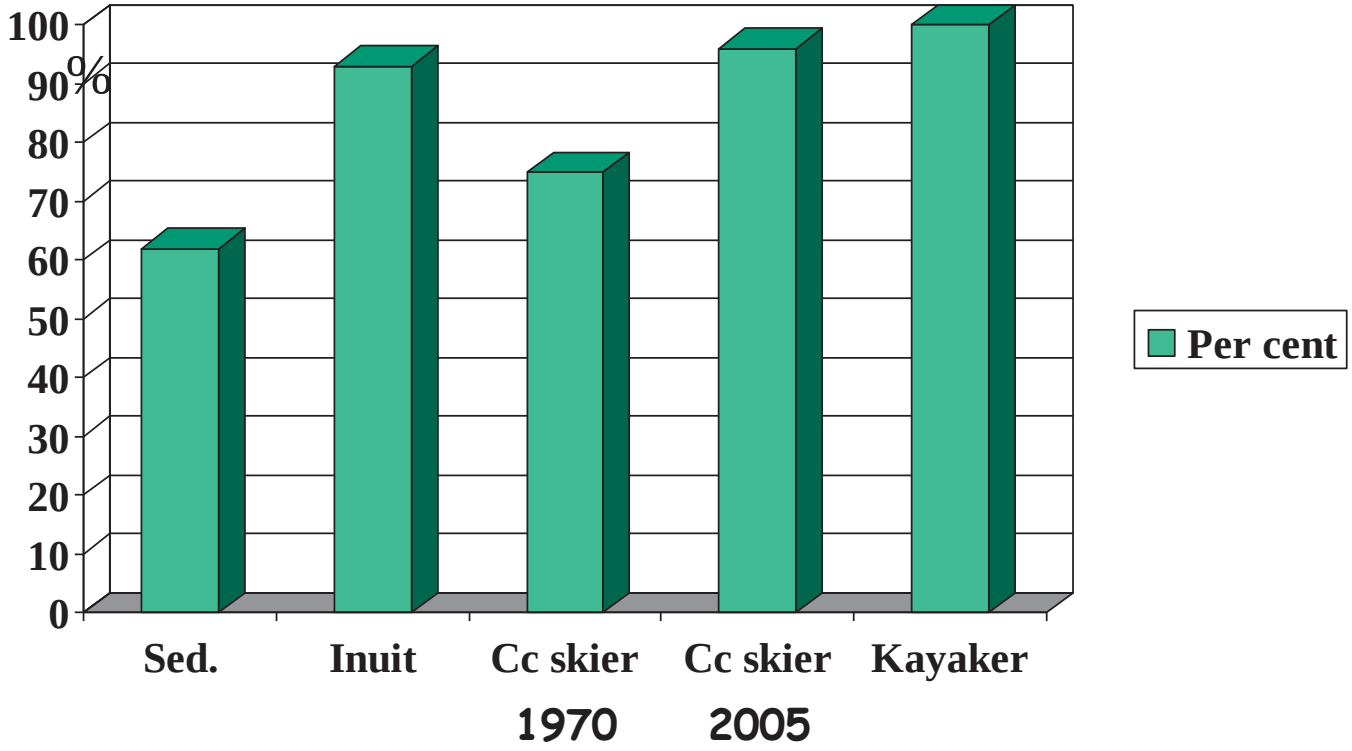
Abs_VO_2: 4.6
Rel_VO_2: 70

Abs_VO_2: 3.7
Rel_VO_2: 78

High absolute VO_2peak, skiing efficiency and ΣO_2 deficit
Large training volumes: ~1000 h/year

Training effects

Upper vs Lower Body;% VO_2 peak



Performance

VO_2: 6.2/6.4 HR: 178/183 V_E: 189/205

Video
XC Skier uphill
during a race

The "Human Engine"

VO_2 max

> 6 $L \cdot min^{-1}$

> 80 $ml \cdot kg^{-1} \cdot min^{-1}$

Lungs

>200 L · min

(250 L · min)

Heart

>200 mL · beat

>40 L blood · min

Muscles

2-3 x untrained

Work duration:

4x2-4 min

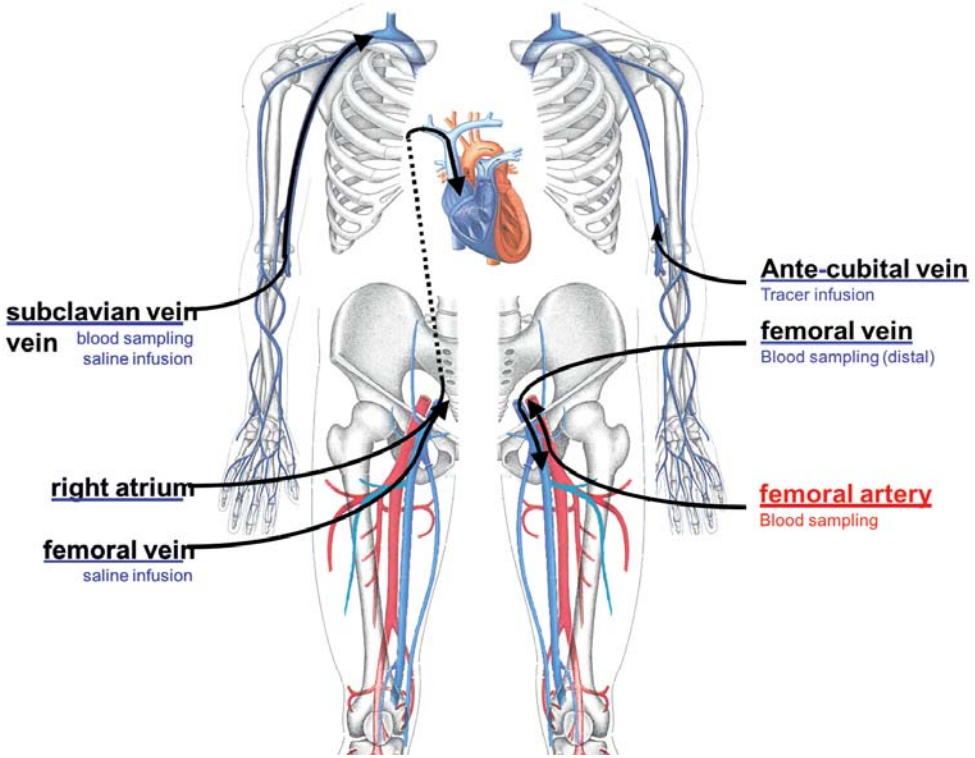
approx. 2 hrs

J Physiol 558.1 (2004) pp 319–331

Maximal muscular vascular conductances during whole body upright exercise in humans

Calbet V. Hall Holmberg Rosdahl Urstad Saltin

VO_2 + blood flow



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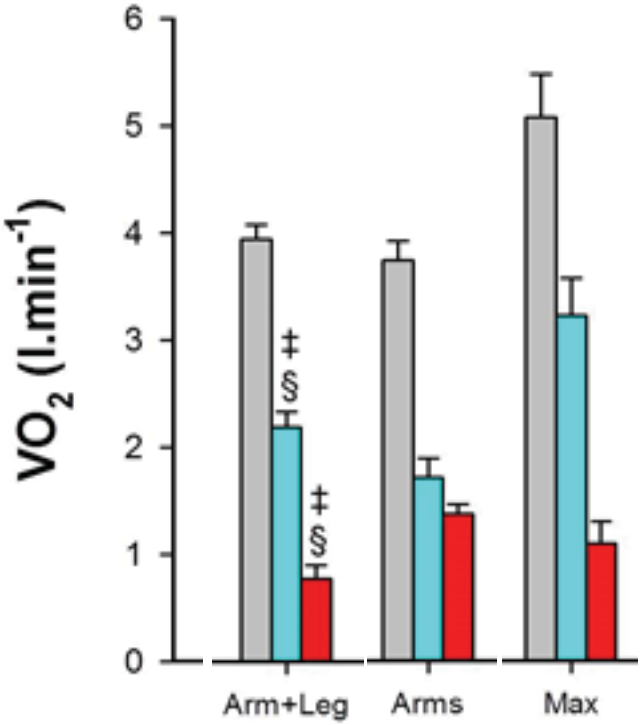


MODERATE/HIGH INTENSITY ENDURANCE TRAINING

Johan Olsson

>85 ml·kg^{-1}·min^{-1}

Video XC Skier
Uphill on a treadmill in the laboratory

Gold 50 K + Silver 15 F

World Championships ITA 2012-2013

Hannes Kolehmainen

4 Olympic Golds + 1 Silver

Gold 10,000 m
1912 Olympics

5-10 x 1000 m
(19 km hr^{-1})

Paavo Nurmi

(The Flying Finn)

9 Olympic Golds + 3 Silver

1920 (14 min 36 s 5000 m)

6x400 m à 60 s

...as a part of 10-20K
distance session in the forest

Rudolf Harbig

1.46.6 sek 800 m running (1939)

2 Olympic Gold + 1 Bronze

30-70 s running ~ HR 180

Start new running when HR decreased to ~120

Dr. H. Reindell

(cardiologist)

used interval training in rehabilitation of heart patients

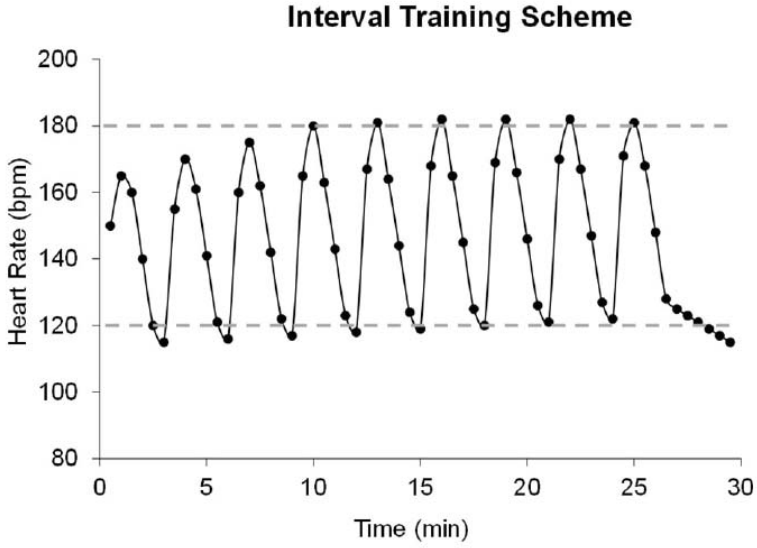
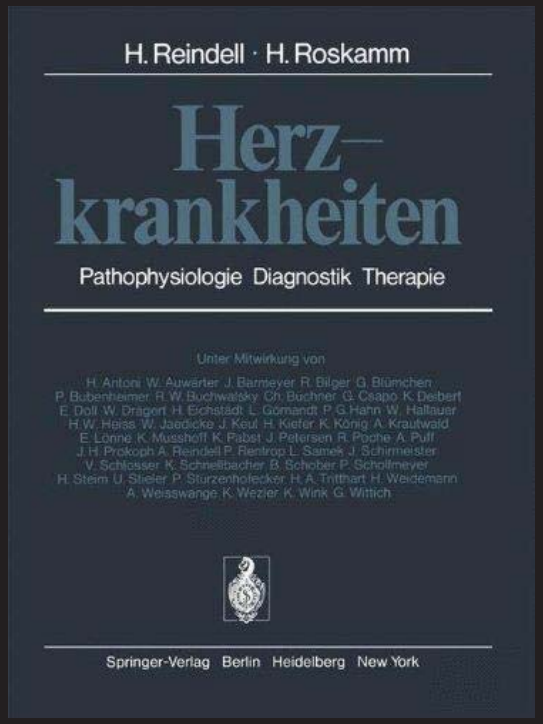


Figure 2 — Schematic of interval training scheme as developed by Gerschler and Reindell. The athlete would run a certain distance (400 m in this example) followed by a certain recovery interval. The hard segment should be adequate to increase the heart rate to 180, and the recovery interval should be adequate to allow it to decrease to 120. If the heart rate failed to recover adequately, then either the speed or duration of the hard segment should be decreased, or the workout should be terminated.

First to describe interval training in a scientific journal (*Sch Z Sportsmed* 1959; 7: 1-8)



1950-

Emil Zatopek

7 Olympic Golds + 1 Silver + 1 Bronze

- 13.57 5,000 m
- 28.54 sek 10,000 m

- 40x400 m at 5000 m velocity w. start every 2 min

Structured and natural interval training etablished as a central part of the training in middle/long distance running

Arthur Lydiard

AUS trainer

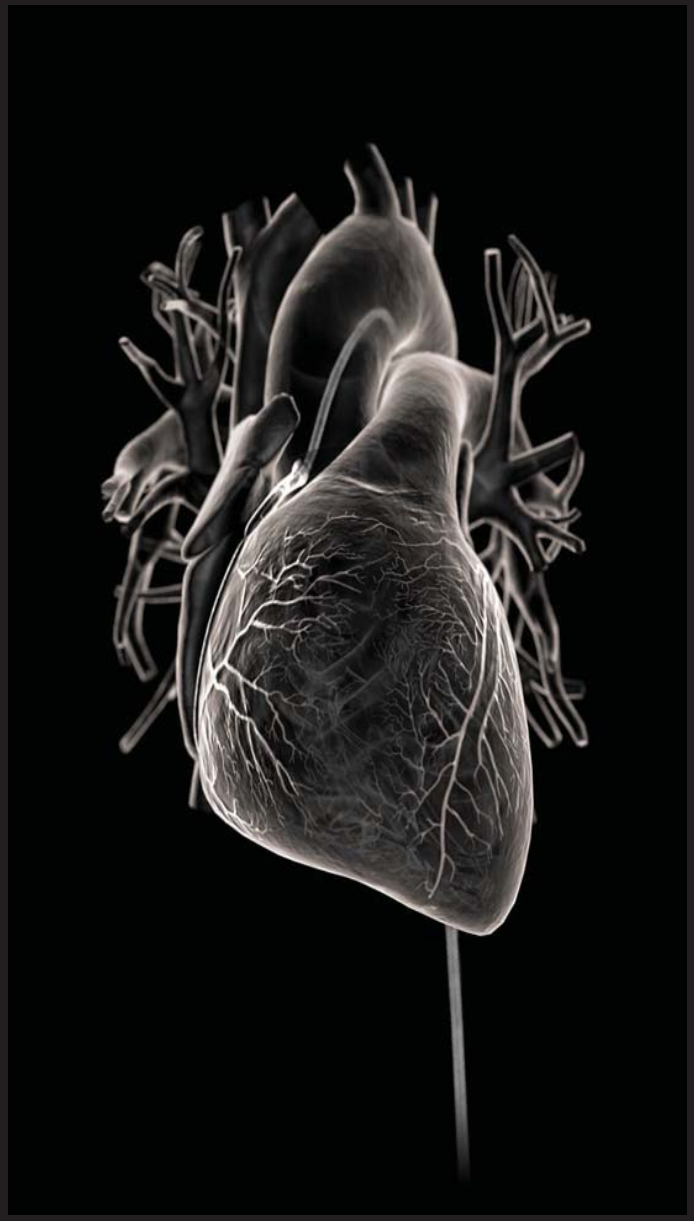
Peter Snell

3 Olympic Golds
Rome 1960: 2
Tokyo 1964: 1

Short interval 10-15 s at 100% vVO_{2max}

In addition, long runs ~2 hrs

LSD (Long Slow Distance)

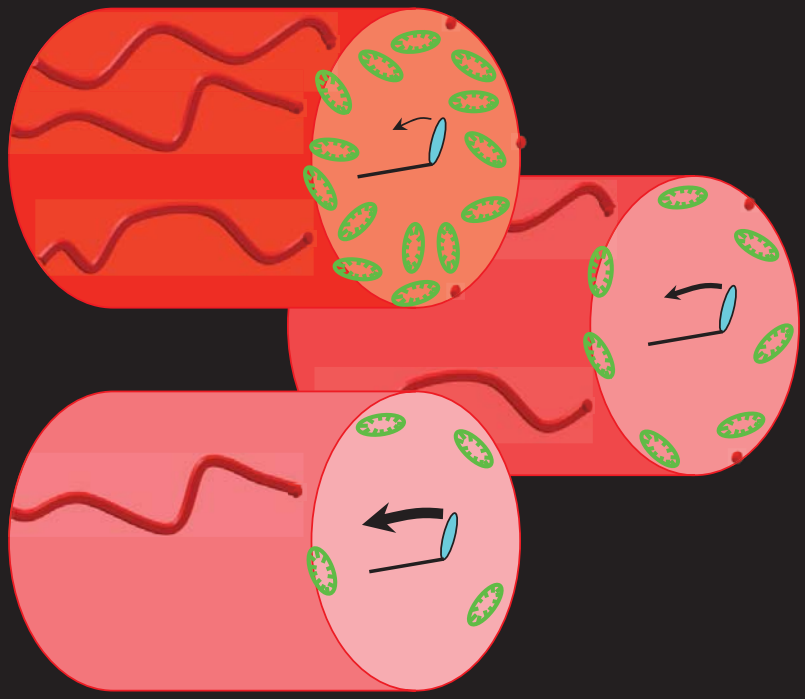


The Scientific Basis for High-Intensity Interval Training

Optimising Training Programmes and Maximising Performance in Highly Trained Endurance Athletes

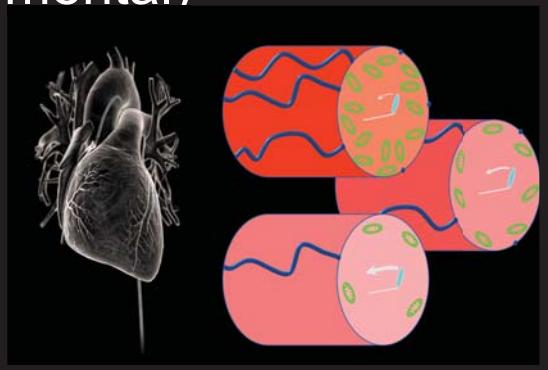
Paul B. Laursen and *David G. Jenkins*

School of Human Movement Studies, University of Queensland, Brisbane, Australia



Increase the capacity

1. Develop the ability run/ski/row fast (technique, tactical, mental)
2. Maximal oxygen uptake (VO_2max) ⇑
3. Peripheral factors (mm) ⇑
4. Stimulate anaerobic capacity

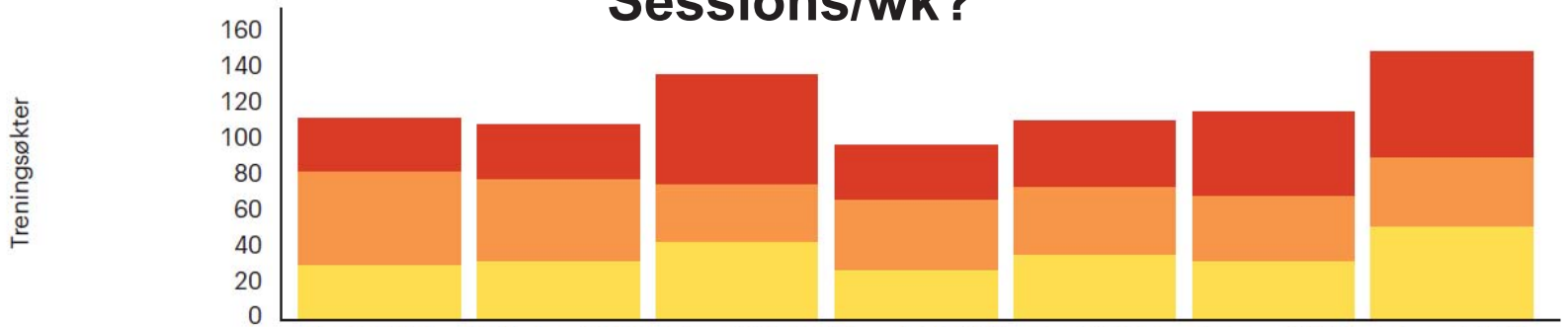


HI

MID

LOW

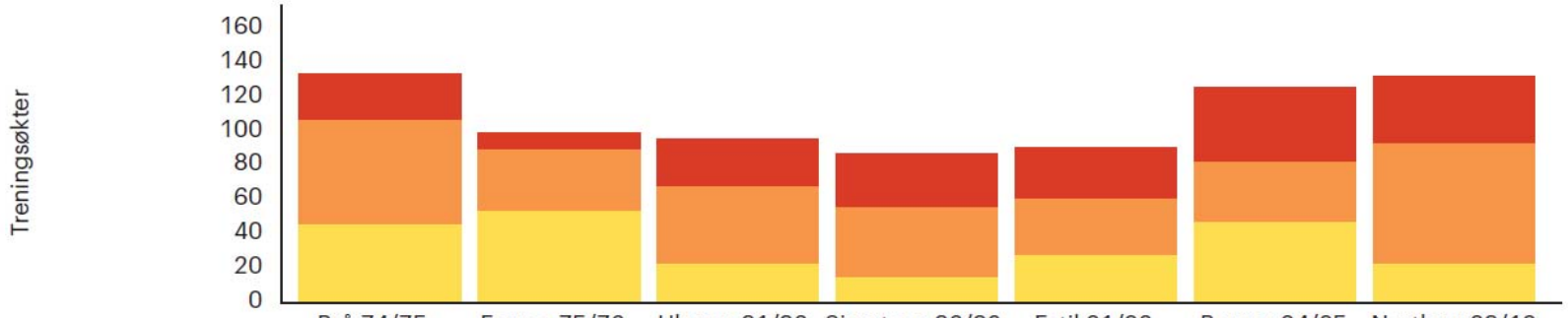
Sessions/wk?



		Aunli 81/82	Nykkelmo 84/85	Jahren 86/87	Dybendahl 90/91	Skari 01/02	Bjørgen 09/10	Johaug 10/11
I5-økter		32	32	60	30	37	46	58
I4-økter		49	43	36	39	37	35	37
I3-økter		32	35	41	26	35	33	52

110-140 sessions w high(-er) intensity/yr

2-3/wk



		Brå 74/75	Formo 75/76	Ulvang 91/92	Sivertsen 92/93	Estil 01/02	Berger 04/05	Northug 09/10
I5-økter		26	9	26	31	30	43	39
I4-økter		59	36	46	38	31	33	68
I3-økter		45	53	22	16	28	46	23

Block periodization

5x4/3

90-95% HR_{max}

Aerobic endurance training improves soccer performance

JAN HELGERUD, LARS CHRISTIAN ENGEN, ULRIK WISLØFF, and JAN HOFF

MSSE, 2001

4x4/3 min

2 days/wk

8 wk

Specific endurance training
= not enough

	TG		CG	
VO_2 max	4.25	4.59	4.06	4.11

+8%

WORK: 8-15 min - REST: ca 25 % - TOT: 45-90 min

1. 5 x 10 min (rest: 2.5 min)
2. 6 x 8 min (rest: 2 min)
3. 4 x 10-15 min (rest: 3-4 min)
4. 45-60 continous work (1 of 4 MOD/HI-sessions)

WORK: 2-5 min - REST: ca 75% - TOT: 15-25 min

1. 6 x 3 min (rest: 2 min)
2. 4-5 x 4-5 min (rest: 3 min)
3. 2-2-3-3-2-2-1-1 (rest: 1-2 min)
4. 3-4-5-4-3 (rest: 2-3 min)

WORK: 5-8 min - REST: ca 50% - TOT: 20-45 min

1. 6 x 5 min (rest: 2 min)
2. 5 x 7 min (rest: 4 min)
3. Pyramide: 2-8 min work – Rest: 1-4 min (TOT: 30-40 min)
4. ”Hilly terrain: 30-40 min

Video

Elite athletes
– performing HI-interval training in the field

NRC Research Press

CLINICAL CORNER

Is high-intensity interval training a time-efficient exercise strategy to improve health and fitness?

Jenna B. Gillen and Martin J. Gibala

Abstract: Growing research suggests that high-intensity interval training (HIIT) is a time-efficient exercise strategy to improve cardiorespiratory and metabolic health. "All out" HIIT models such as Wingate-type exercise are particularly effective, but this type of training may not be safe, tolerable or practical for many individuals. Recent studies, however, have revealed the potential for other models of HIIT, which may be more feasible but are still time-efficient, to stimulate adaptations similar to more demanding low-volume HIIT models and high-volume endurance-type training. As little as 3 HIIT sessions per week, involving ≤10 min of intense exercise within a time commitment of ≤30 min per session, including warm-up, recovery between intervals and cool down, has been shown to improve aerobic capacity, skeletal muscle oxidative capacity, exercise tolerance and markers of disease risk after only a few weeks in both healthy individuals and people with cardiometabolic disorders. Additional research is warranted, as studies conducted have been relatively short-term, with a limited number of measurements performed on small groups of subjects. However, given that "lack of time" remains one of the most commonly cited barriers to regular exercise participation, low-volume HIIT is a time-efficient exercise strategy that warrants consideration by health practitioners and fitness professionals.

Key words: interval training, exercise intensity, training adaptations.

Résumé : De plus en plus d'études suggèrent que la méthode d'entraînement par intervalle de haute intensité (« HIIT ») est économique en matière de temps investi pour l'amélioration de la santé cardiorespiratoire et métabolique. Les approches « à fond de train » comme les exercices de type Wingate sont particulièrement efficaces, mais ce mode d'entraînement n'est peut-être pas sécuritaire, facile à tolérer et pratique pour bien des individus. Des études récentes révèlent le potentiel d'autres modèles HIIT — apparemment plus pratiques et aussi efficaces — pour susciter des adaptations similaires aux plus exigeants modèles HIIT à faible volume et d'entraînement en endurance à haut volume. À raison d'aussi peu que trois séances HIIT par semaine comprenant ≤ 10 min d'exercice intense dans une séance de ≤ 30 min incluant l'échauffement, la récupération entre les intervalles et le retour au calme, on améliore la capacité aérobie, la capacité oxydative du muscle squelettique, la tolérance à l'effort et les marqueurs du risque de maladie, et ce, après seulement quelques semaines tant chez des individus en bonne santé que chez des personnes aux prises avec des troubles cardiométaboliques. Il faut réaliser d'autres études, car celles qui ont été effectuées présentaient des résultats à court terme avec un nombre limité de mesures enregistrées auprès de petits groupes de sujets. Cependant, « le manque de temps » étant l'argument généralement évoqué comme obstacle à la pratique régulière de l'activité physique, un programme HIIT à faible volume constitue une approche efficace que devraient prendre en compte les praticiens de la santé et les professionnels de la condition physique. [Traduit par la Rédaction]

Mots-clés : entraînement par intervalle, intensité de l'exercice, adaptations à l'entraînement.

Current physical activity guidelines including those from the Canadian Society for Exercise Physiology (CSEP) recommend that adults should accumulate at least 150 min of moderate- to vigorous-intensity aerobic physical activity per week to achieve health benefits (Tremblay et al. 2011). The CSEP guidelines do not specifically define intensity ranges; however, guidelines from other agencies, including the American College of Sports Medicine, classify moderate intensity as 64%–76% of maximal heart rate (HR_{max}) (46%–63% of maximal oxygen uptake (VO_{2max})) and vigorous intensity as 77%–95% of HR_{max} (64%–90% VO_{2max}) (Garber et al. 2011). While public health guidelines are based on very strong scientific evidence, accelerometer data indicate that as many as 85% of Canadians do not meet the minimum physical activity recommendations (Colley et al. 2011) with "lack of time" being one of the most commonly cited barriers to regular participation (Trost et al. 2002). Recent evidence from relatively small, short-term studies suggests that high-intensity interval training (HIIT) may be as effective as traditional moderate-intensity continuous training to induce physiological remodelling, which in turn may be associated with improved health markers, despite a reduced time commitment.

What is HIIT?

HIIT is characterized by brief, repeated bursts of relatively intense exercise separated by periods of rest or low-intensity exercise. "Low-volume" HIIT refers to exercise training sessions that are relatively brief — consisting of ≤10 min of intense exercise within a training session lasting ≤30 min including warm-up, recovery periods between intervals and cool down — such that the total weekly exercise and training time commitment is reduced compared with current public health guidelines. One of the most common models employed in low-volume HIIT studies is the Wingate Test, which consists of 30 s of "all-out" cycling against a

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*All editorial decisions for this paper were made by Michelle Porter and Terry Graham.

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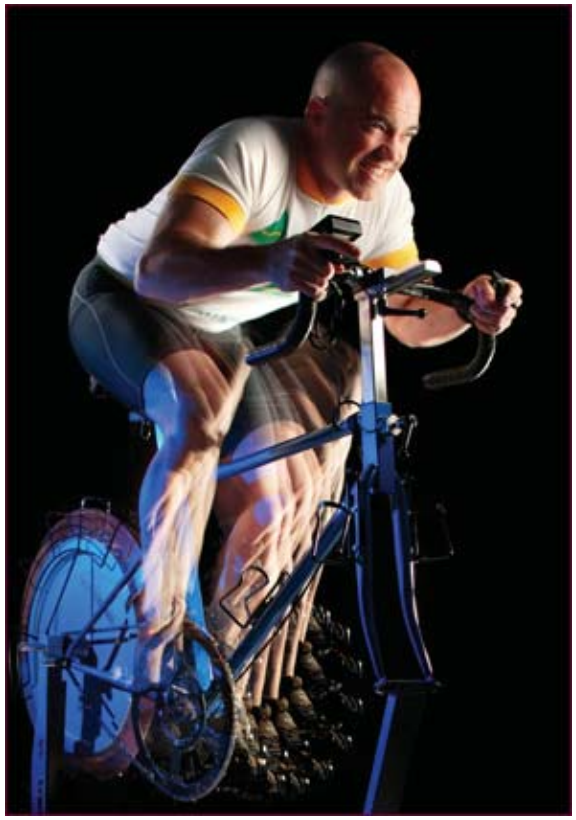
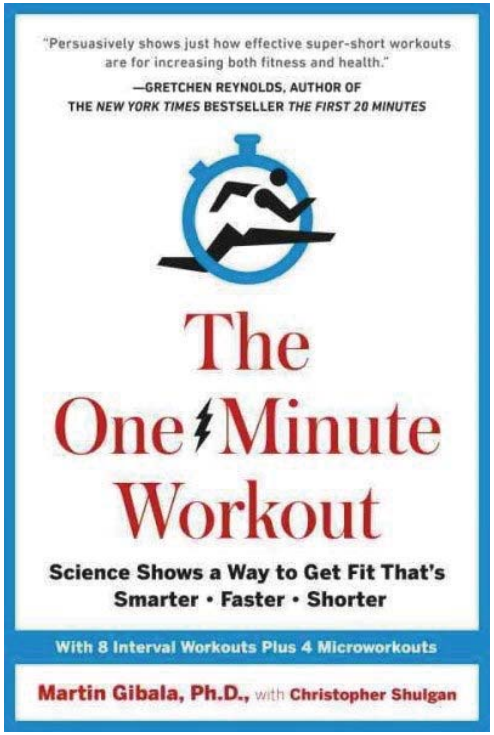




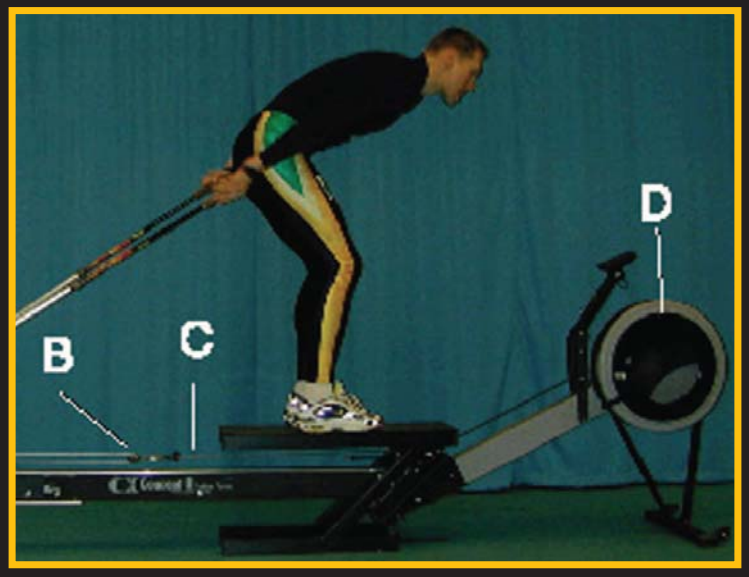
Short HIT interval training – long recovery

3 times / wk: **11-15** intervals

20 s	120 s

Power output	Peak	↑
	30 s	↑
	6 min	↑

Nilsson et al.
EJAP 2004



4-6x30 s work/4.5 min recovery

Power output	↑
VO_2peak	↑
Muscle	↑

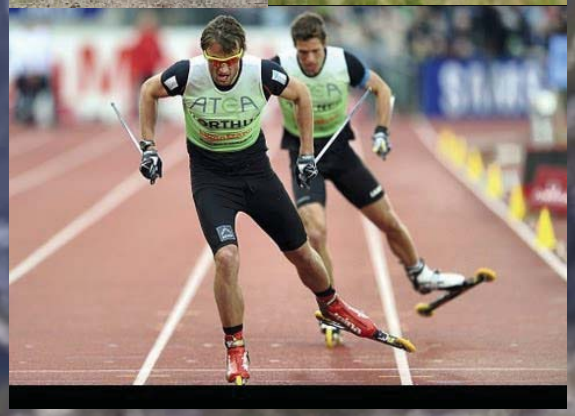
Burgomeister et al.
J Physiol 2008

BASE

Lower intensity

- Develop technique & work economy
- Improve capacity to tolerate training and recover during/after training
- Develop aerobic capacity (VO_2max and the utilization; % of VO_2max)
- Warm up/Cool down
- Recovery btw. training sessions and competitions

General vs. specific training

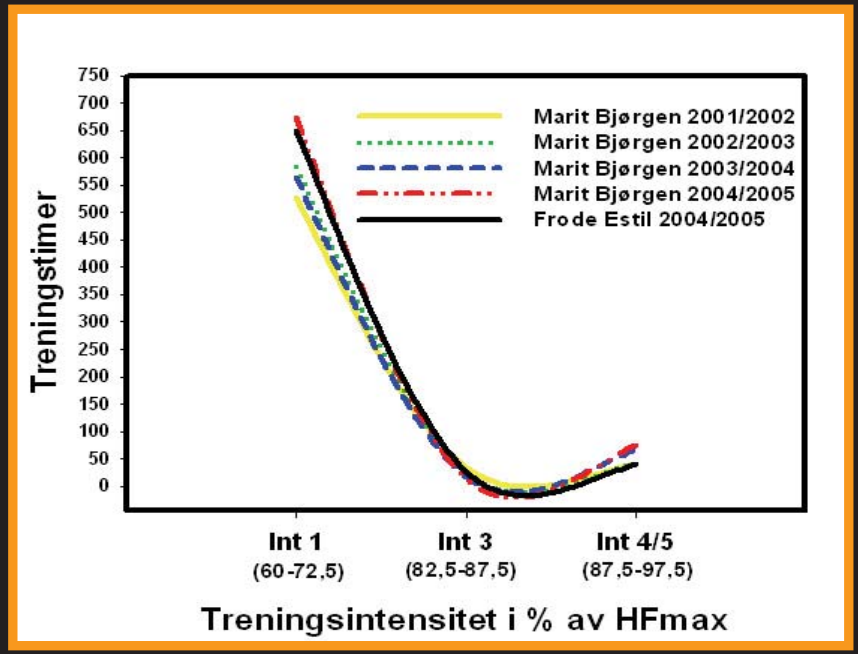


Successful XC skiers

Marit Björgen

Frode Estil

HIGH TRAINING VOLUME



750-850 hrs / yr

10-12 sessions/w

~90% = ENDURANCE training

1-4 h/day

”Train to be able to train what is needed to compete successfully”

The physiology of world-class sprint skiers

Ø. Sandbakk[1], H.-C. Holmberg[2], S. Leirdal[1], G. Ettema[1]

Table 4. Total training performed in the 6 months before testing in world-class and national-class sprint cross country skiers (mean ± SD)

Variables	World-class ($n = 8$)		National-class ($n = 8$)	
	Training hours	% of total training	Training hours	% of total training
LIT	340 ± 23**	76.4 ± 4.6	254 ± 94	73.1 ± 12.0
MIT	29 ± 12**	6.5 ± 2.2*	14 ± 6	4.4 ± 2.4
HIT	19 ± 3	4.4 ± 0.8	19 ± 8	5.6 ± 2.1
Speed	16 ± 7**	3.7 ± 1.5*	7 ± 3	2.3 ± 1.2
Strength	39 ± 14	8.8 ± 2.9	31 ± 14	9.4 ± 3.7
Total	445 ± 27**	100	341 ± 90	100

Scand J Med Sci Sports 2010

Norwegian and Swedish Olympic Committe

- INTENSIVE training is VERY important
- There is not ONE method or ONE intensity level that provide the best training effects on aerobic capacity
- It is the accumulation of the total en endurance training, that leads to higher performance level

Recovery

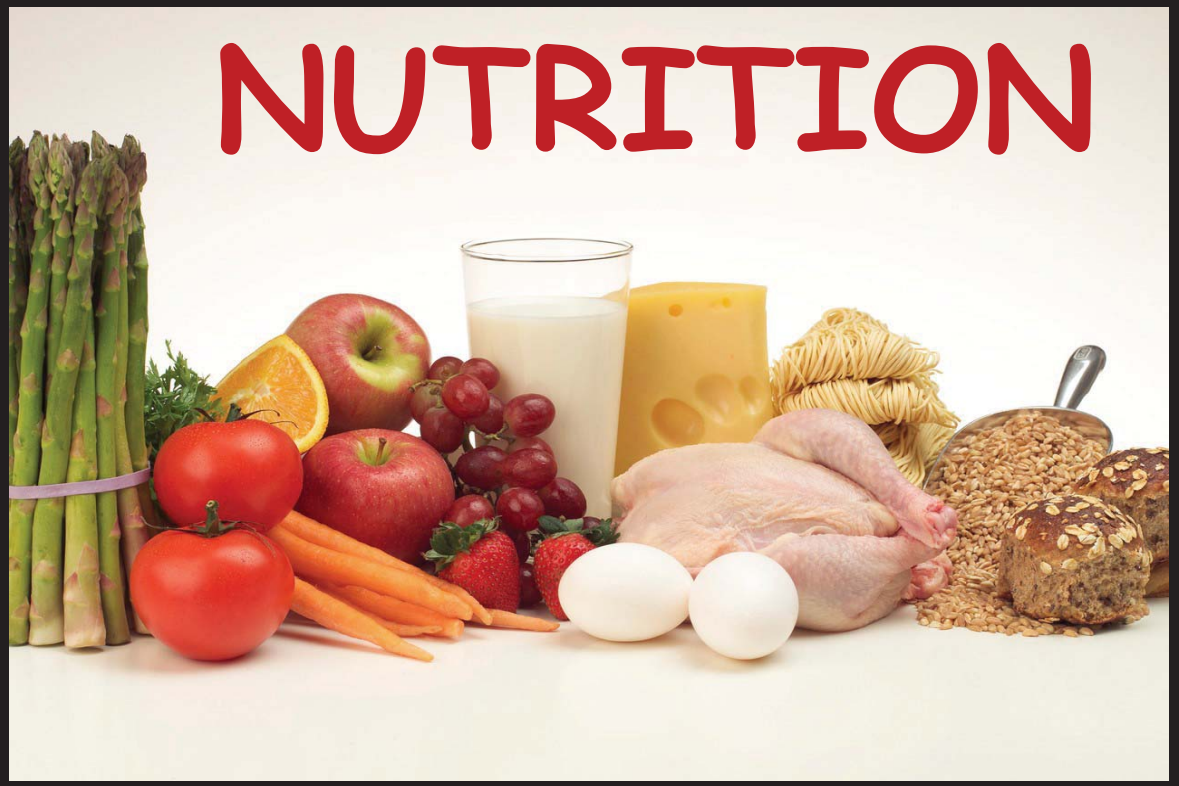
Following sessions

Following a competition

Between training days

Within a competition

NUTRITION



REFUEL
REBUILD
REHYDRATE.
RECOVER

MAJOR PRIORITY

Restoration ENERGY and WATER STORES
before/after training and competition

SLEEP

Swimming (10 h/night (6-7 wks)

- 15 m sprint ⇑
- Reaction time ⇑
- Mood ⇑

Basketball - "sleep as much as possible"

- Sprint ⇑
- FT-% ⇑
- Vigour ⇑

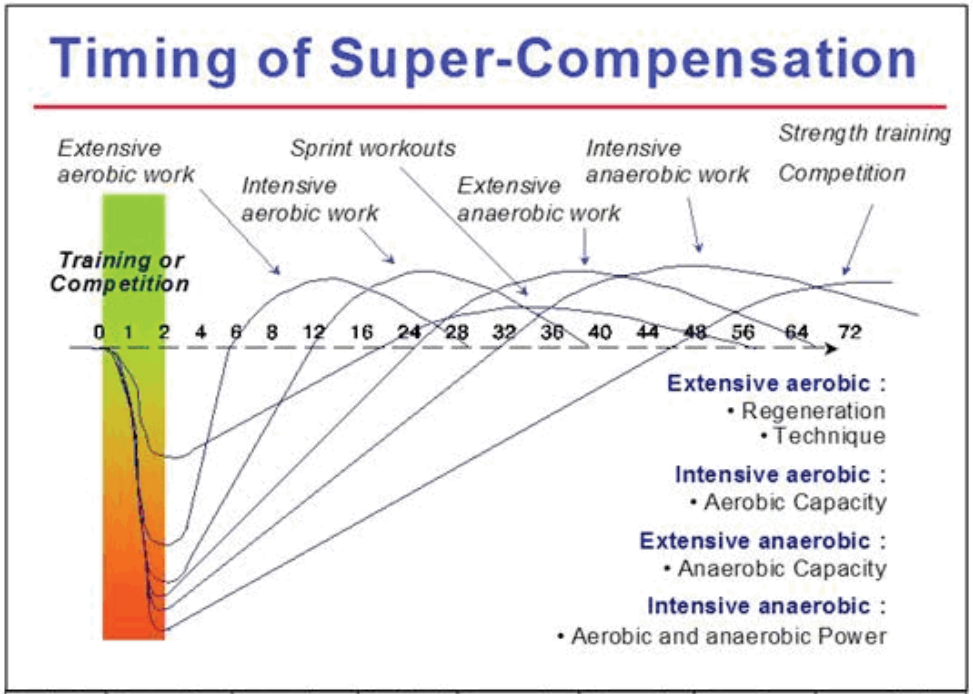
- Fatigue ⇓

"Sleep is extremely
important for me"

*"I think sleep is
as important
as exercise and diet"*

ACTIVE RECOVERY

Sochi Olympics: The Dutch Key to Skating Is Getting on a Bike



Training types	Extensive Endurance	Intensive Endurance	Sprints/ Short Sets	Extensive Anaerobic Training	Extensive Strength Training	Intensive Anaerobic Training	Intensive/ Strength Training/ Competition
From	8	24	30	36	40	40	48
To	12	30	40	48	60	60	72

Plan BOTH
Training & RECOVERY

Recovery

Muscle mass
Fast/Slow muscle fibers
Trainign intensity
Age
Gender

Environmental factors

Training Puzzle

	Morning	Before lunch	After lunch	Evening
Mon	**STR**		LI/MI	
Tues		**HI_LEG**		LI
Wed			M/LI	
Thurs		LI/LEG	**HI_UB**	
Fri	**STR**		LI/MI	
Sat	LI/WB		**HI_UB**	
Sun	R	E	S	T

Most XC SKIERS train 10-12 per week w 1-1/2 REST days

Training Puzzle

	Morning	Before lunch	After lunch	Evening
Mon		END/HI		END/LI-CORE
Tues		STR-L		
Wed		STR	R	E
Thurs	S	T	END-MED/HI	
Fri		STR-L		CORE/ COORD.
Sat		STR		END/LI-MI
Sun	R	E	S	T

3-4 END sessions per week
3-4 STR sessions per week
1-3 Other sessions per week (for ex. core/balance/koordination)

INCREASED

TRAINING LOAD

NUTRITION + SLEEP

Individual training response


PyeongChang 2018


TOKYO 2020


Beijing 2008
TM©

Rio2016™

GOLD x 1
SILVER x 1
BRONZE x 1

GOLD x 1

vancouver 2010

8/14

57%

sochi.ru 2014

11/15

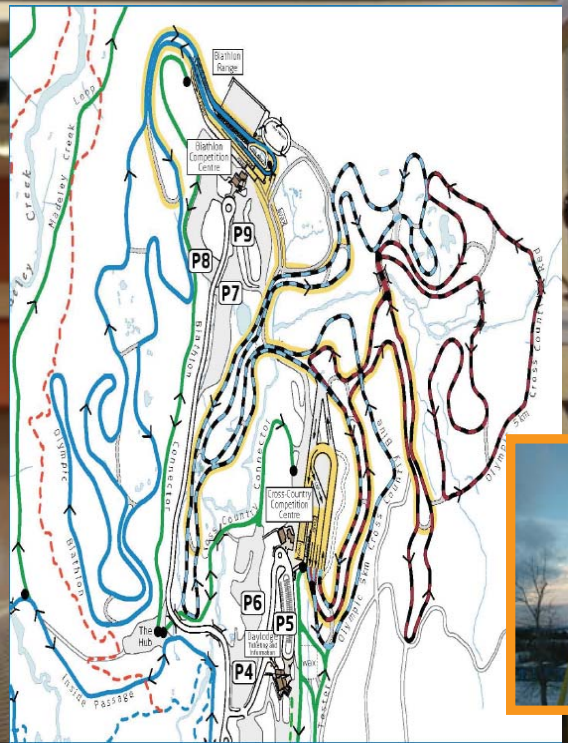
73%

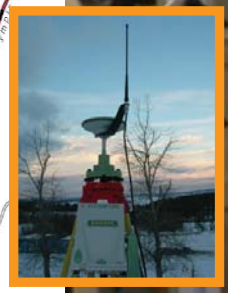
22/36

Olympic Tracks

Aftenposten.no #1 ÅRETS NETTSTED

"Svenskenes hemmelighet"





2010

COURSE SIMULATOR

HÄR HYLLAS DE BÅDA SVENSKA HJÄLTARNA

STYRS AV TRE DATORER

All information och alla värden sammanlänkas av tre datorer i rummet. 50 gånger per sekund "pratar" datorerna med varandra.

I källaren finns dessutom en frekvensomvandlare som styr bandets hastighet och lutning.

TRE BILDSKÄRMAR VÄGLEDER

PULSEN
Hur välträinad är jag? De aktiva kan följa sin hjärtfrekvens online på skärmen framför sig när de åker banorna.

OS-BANAN I WHISTLER
Hur tung var värsta backen? Spåren i Whistler har filmats från skoter av ett forskarteam från Vintersportcentrum. Kurvor och lutning har samtidigt registreras med hjälp av GPS.

BANPROFILM M
Vad väntar runt hörnet? Här får den aktive snabbt en uppfattning om banprofilen, nuvarande hastighet och bandets lutning.
Med hjälp av en rund ring får åkaren information om i vilken av bandets tre zoner han/hon befinner sig.

HÖGTALARE

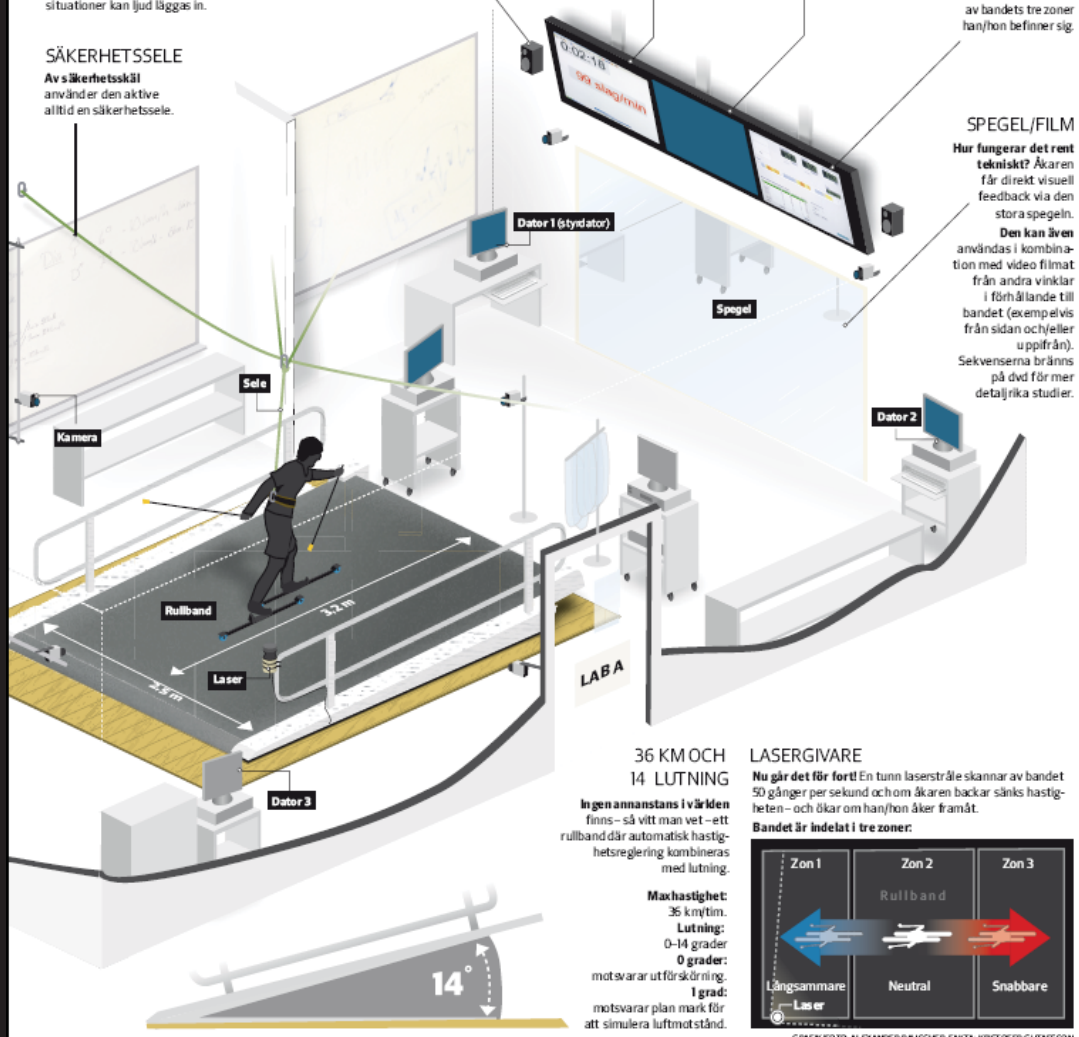
Hörde jag publikens jubel? För att s(t)imulera olika miljöer och situationer kan ljud läggas in.

SÄKERHETSSELE

Av säkerhetsskäl använder den aktive alltid en säkerhetssele.

SPEGEL/FILM

Hur fungerar det rent tekniskt? Åkaren får direkt visuell feedback via den stora spegeln.
Den kan även användas i kombination med video filmat från andra vinklar i förhållande till bandet (exempelvis från sidan och/eller uppifrån). Sekvenserna brännS på dvd för mer detaljrika studier.



36 KM OCH 14 LUTNING

Ingen annanstans i världen finns – så vitt man vet – ett rullband där automatisk hastighetsreglering kombineras med lutning.

Maxhastighet:
36 km/tim.
Lutning:
0–14 grader
0 grader:
motsvarar utförskörning.
1 grad:
motsvarar plan mark för att simulera luftmotstånd.

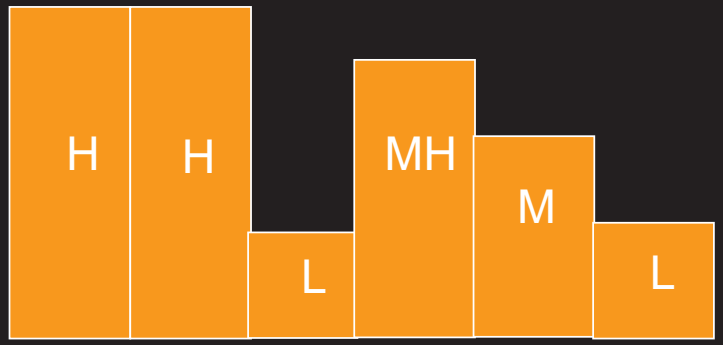
LASERGIVARE

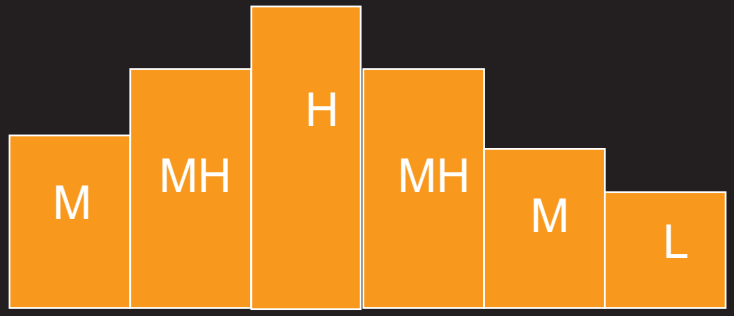
Nu går det för fort! En tunn laserstråle skannar av bandet 50 gånger per sekund och om åkaren backar sänks hastigheten – och ökar om han/hon åker framåt.

Bandet är indelat i tre zoner:

GRAFIK/FOTO: ALEXANDER RAUSCHER FAKTA: KRISTOFER GUTAFSSON

Final 5-6 wk before a championship





Improvement?

1-3% ?

More ?

Less

H.-C. HOLMBERG

PyeongChang 2018

February 10-25

100

days

Development

1+1 = 3

Video

Smart Organization
Alpine Skiing

PERFORMANCE TECHNOLOGY

2010

sochi.ru 2014

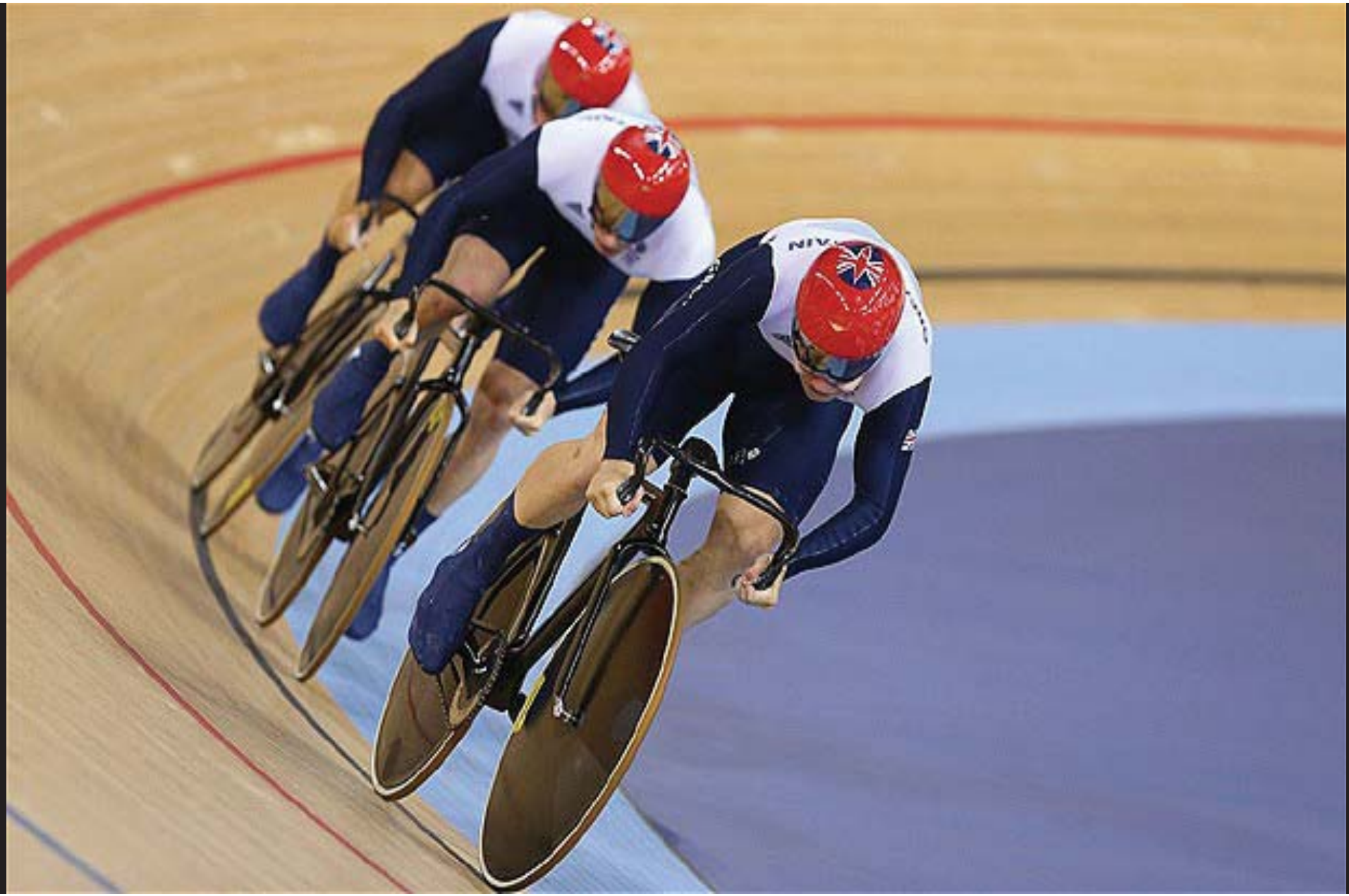
vancouver 2

Munich 1972

1970

Smart Organization

Athlete Centered, Coach Driven, Service Supported (Performance Based)



SWOT-analys

STRENGTHS	WEAKNESSES
OPPORTUNITIES	THREATS


Biomechanics
Physiology


Biomechanics
Brasil
MÉXICO
Physiology

Biomechanics

Physiology

Physiology

Biomechanics

Internet of Sports


THINK
OUTSIDE
THE
BOX

Closing words…

BASIC

Keep it simple

Thanks for your attention