Ageing and Maximal Physical Performance

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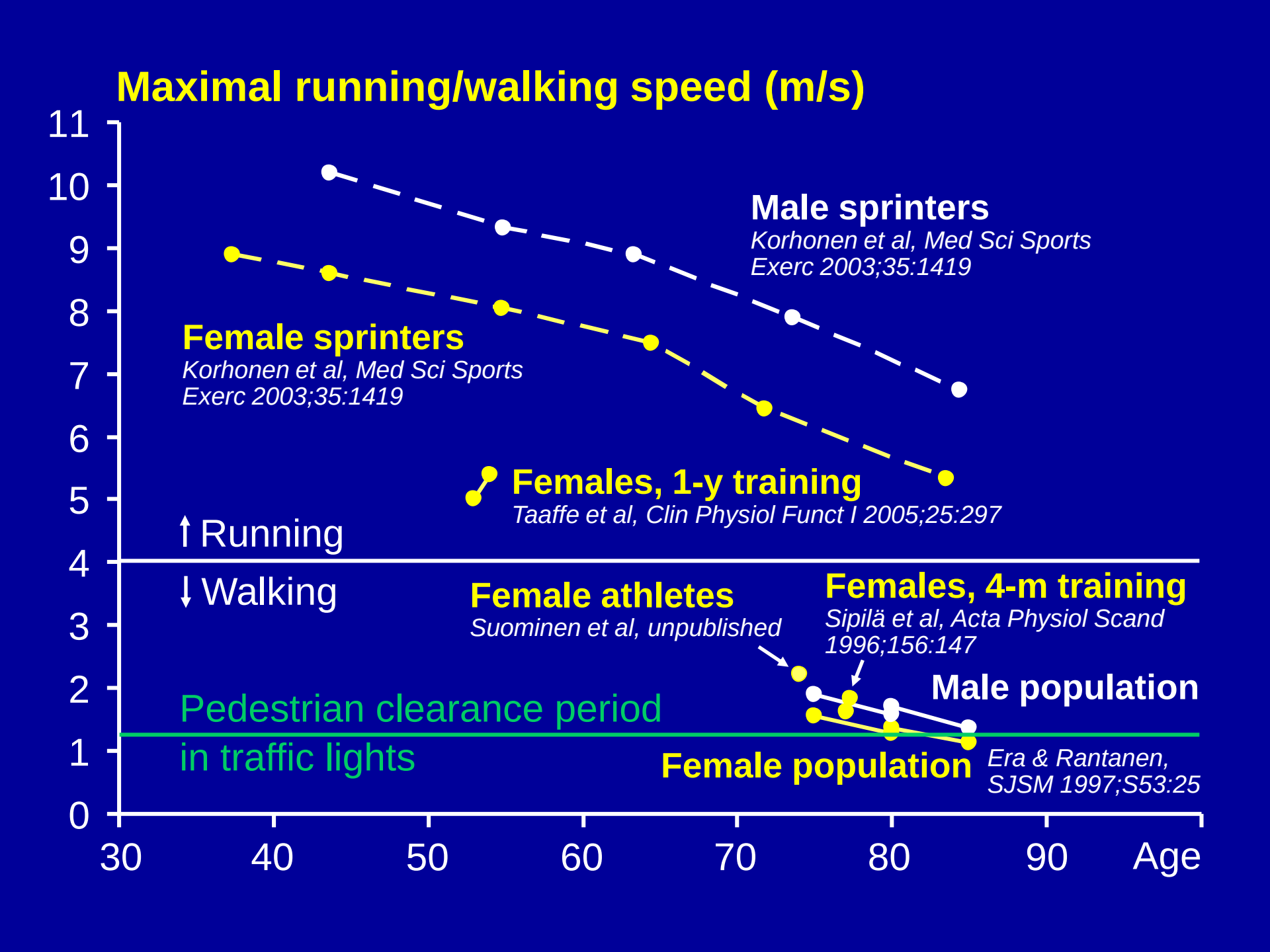
Background

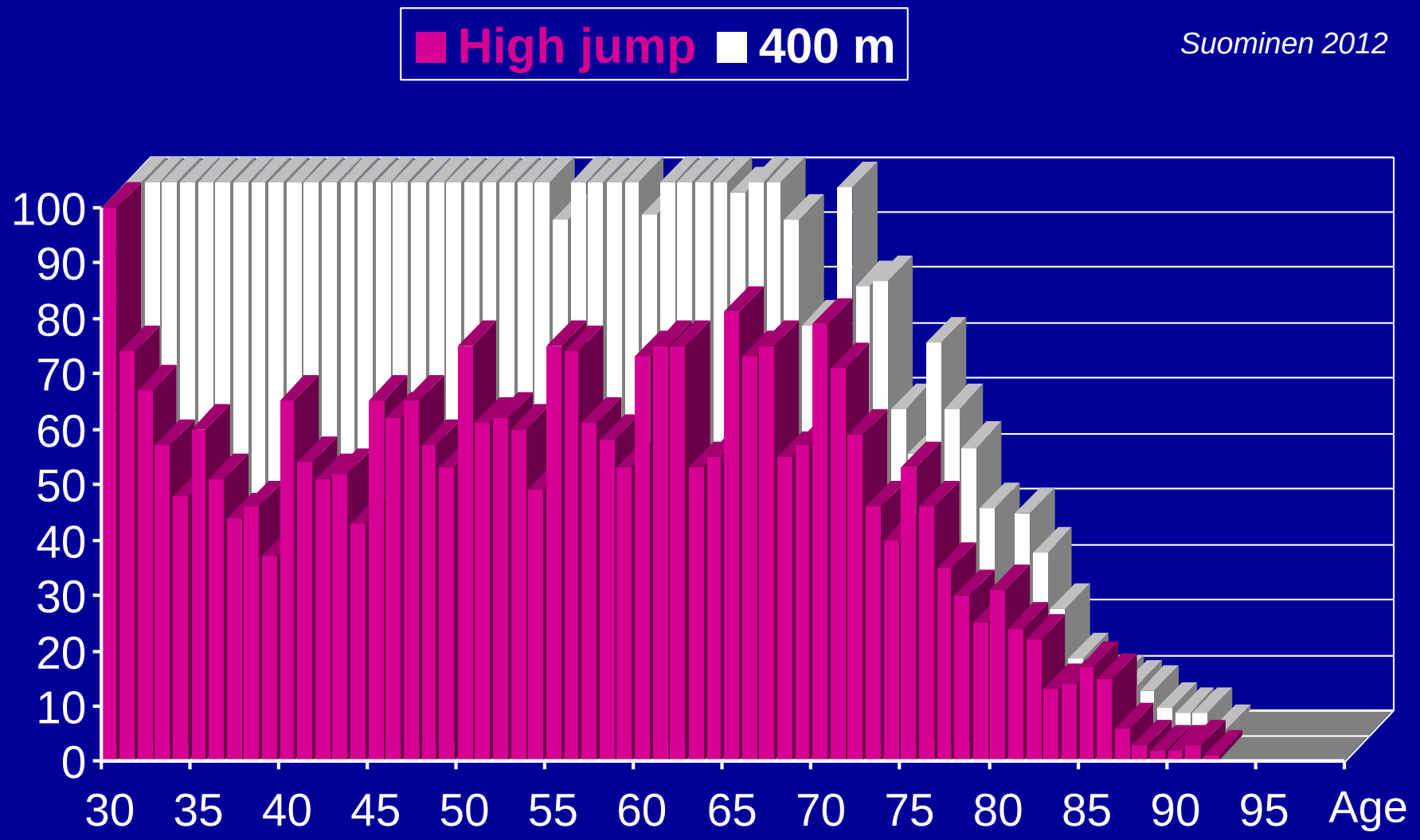
- Preserving adequate physical performance is an essential element of health and functioning among the ageing population
- The greater the reserve capacity in functions such as muscle strength, speed, and endurance, the greater is the potential for elderly people to prolong an active and independent life
- Master athletes with long-term devotion to physical training offer an economical means of investigating the role of exercise in the prevention of age-related decrements in physiological capacities and function
- Highly motivated athletes provide official and controlled performance data and offer a barometer of what is possible in physical health and ageing
- Ideally, the athletes could provide us a model of successful ageing, where the age-related changes are less influenced by factors such as sedentary life-style and chronic diseases


Maximal running/walking speed (m/s)
11
10
9
8
7
6
5
4
3
2
1
0
30
40
50
60
70
80
90
Age
Male sprinters
Korhonen et al, Med Sci Sports Exerc 2003;35:1419
Female sprinters
Korhonen et al, Med Sci Sports Exerc 2003;35:1419
Females, 1-y training
Taaffe et al, Clin Physiol Funct I 2005;25:297
Running
Walking
Female athletes
Suominen et al, unpublished
Females, 4-m training
Sipilä et al, Acta Physiol Scand 1996;156:147
Male population
Female population
Era & Rantanen, SJSM 1997;S53:25
Pedestrian clearance period
in traffic lights

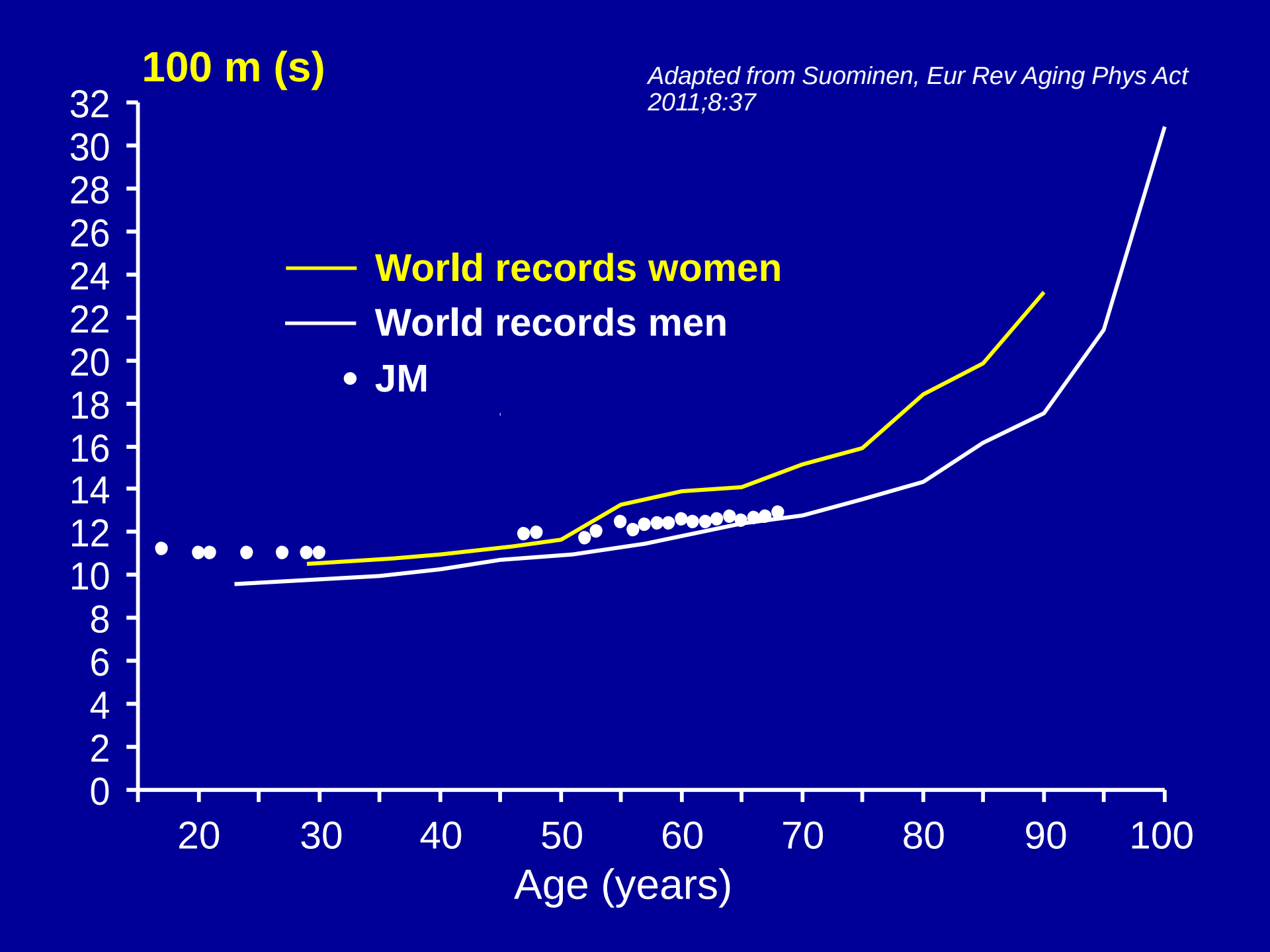
Record performances

- Describing maximal physical performance throughout the life span
- Comparing the age-related changes in athletic events imposing different demands on training and functional abilities
- Taking the absolute best records in each age category provides a straightforward approach to the upper limits of human performance compared to calculating averages from different sources of statistics compiled for athletes or trying to obtain representative performance results for all athletes participating in given sports.

Completing “All-Time Top 100” lists in track and field

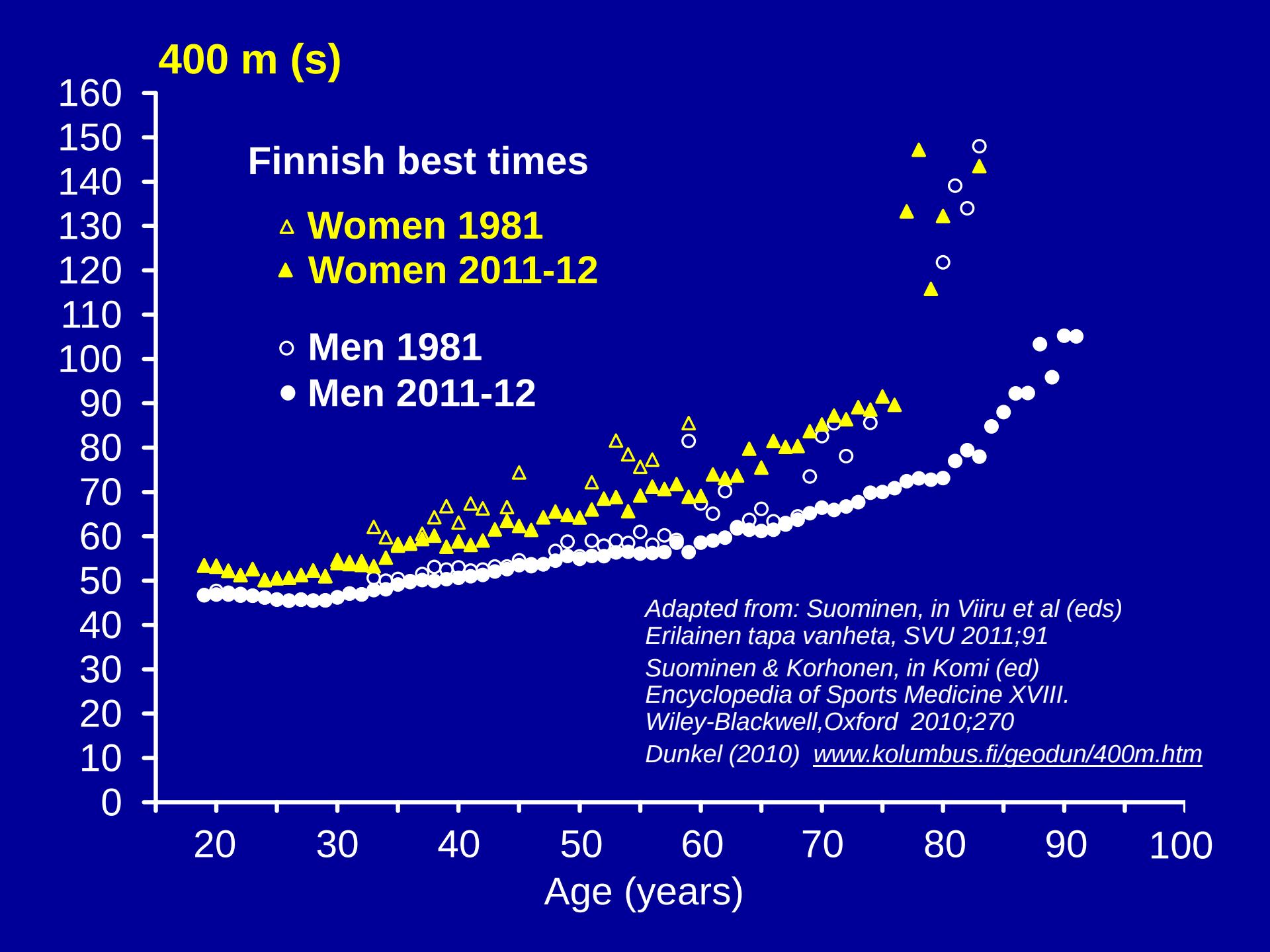


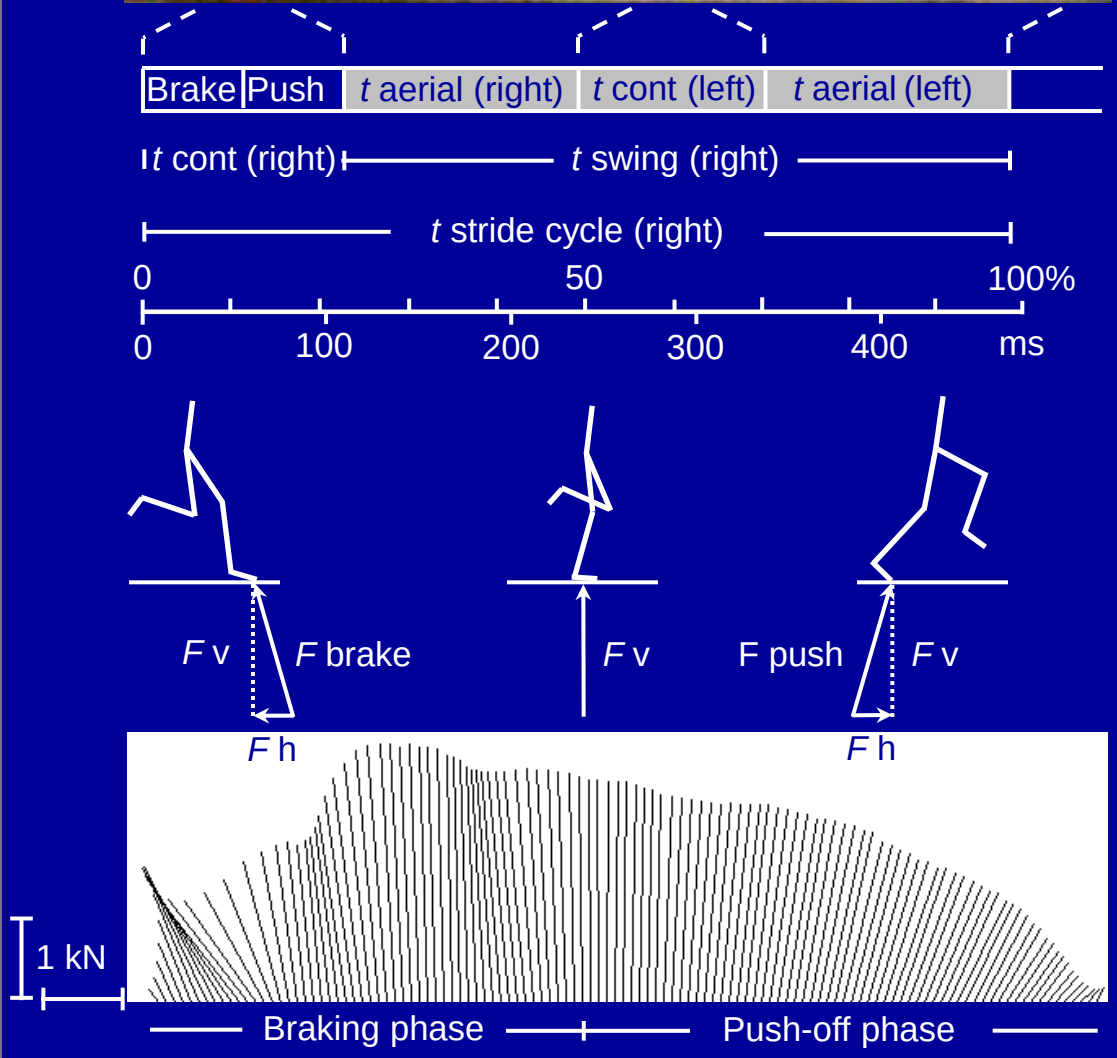
Data from Sarna 2012, www.kttl.helsinki.fi/sarna/Pomppu
Dunkel 2010, www.kolumbus.fi/geodun/400m.htm


100 m (s)
Adapted from Suominen, Eur Rev Aging Phys Act 2011;8:37
World records women
World records men
JM
32
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
20
30
40
50
60
70
80
90
100
Age (years)

Remarks

- 100-m sprint is a strength and speed event, where a great many highly trained athletes regularly compete at a high international event
- A modest curvilinear in running speed until approximately 80 years of age in men and 75 years of age in women
- However, it is obvious that the older champions have never performed as well as their present-day young counterparts
- Individual longitudinal data may show a much smaller decrement over the years compared to the decline estimated from the world records
- As more elite competitors continue to train and participate in the masters' athletics in the older age groups, it is likely that the current records, even in this highly competed event, will further improve


400 m (s)
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
Finnish best times
Women 1981
Women 2011-12
Men 1981
Men 2011-12
Adapted from: Suominen, in Viiru et al (eds) Erilainen tapa vanheta, SVU 2011;91
Suominen & Korhonen, in Komi (ed) Encyclopedia of Sports Medicine XVIII. Wiley-Blackwell,Oxford 2010;270
Dunkel (2010) www.kolumbus.fi/geodun/400m.htm
20
30
40
50
60
70
80
90
100
Age (years)

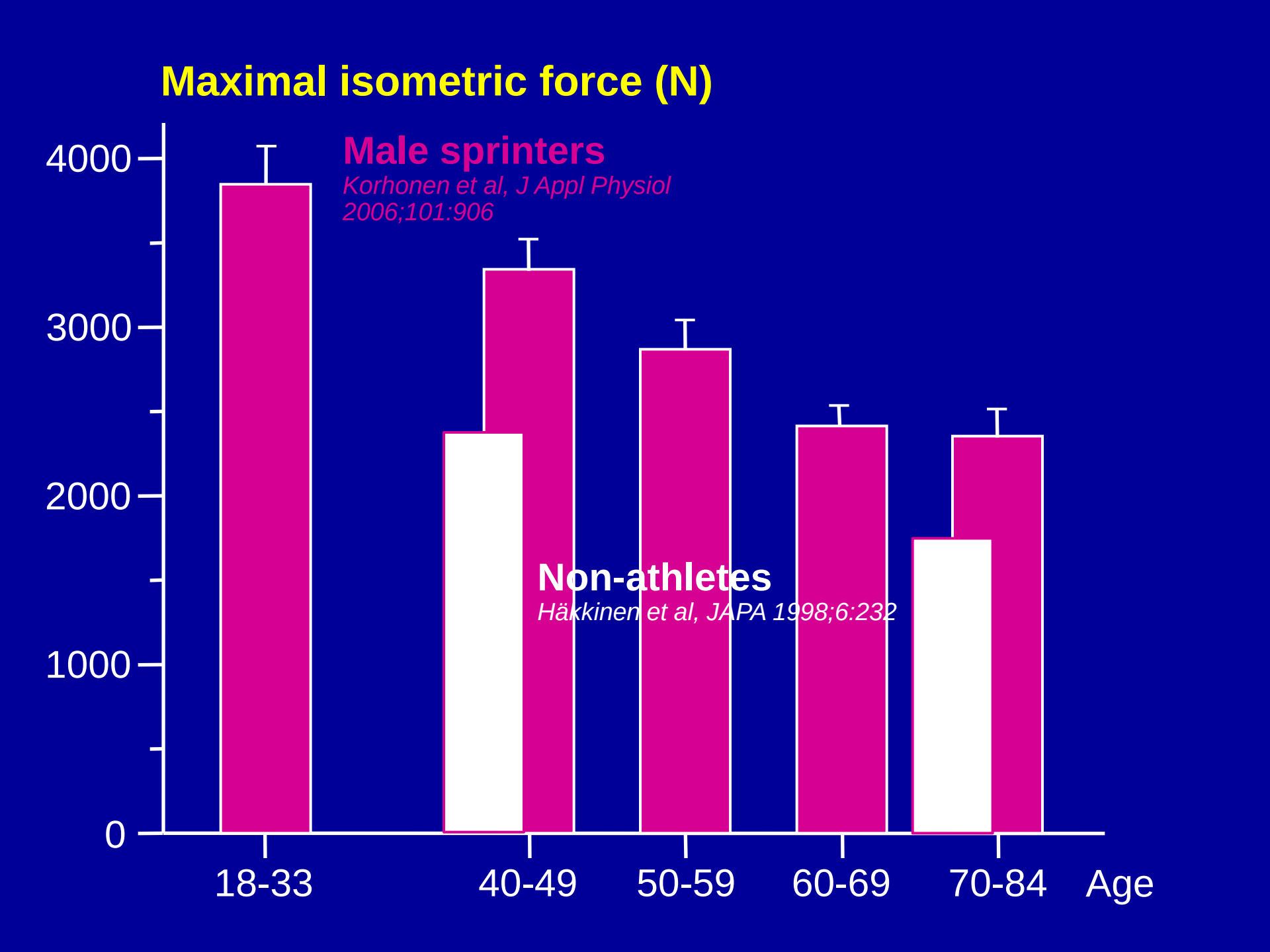


Korhonen et al, Med Sci Sports Exerc 2009;41:844

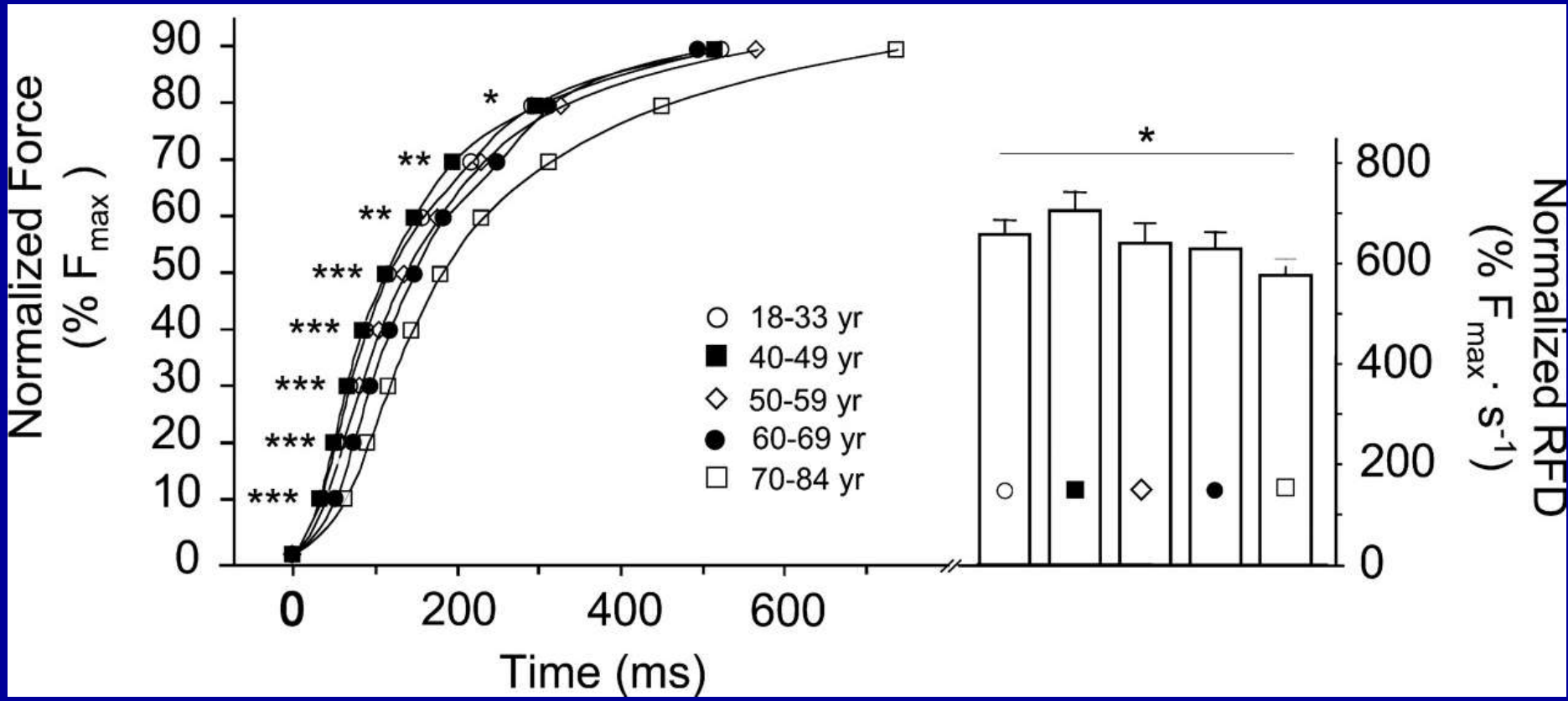
Ground reaction force and kinematic parameters of sprint running in young and older sprinters

	18-33-yr (n=17)	65-85-yr (n=23)	*p*
Resultant braking GRF (bw)	2.70 (0.25)	2.40 (0.29)	.001
Resultant propulsive GRF (bw)	1.90 (0.15)	1.61 (0.20)	<.001
Step length (m)	2.16 (0.07)	1.77 (0.11)	<.001
Step frequency (Hz)	4.34 (0.26)	4.14 (0.28)	.027
Contact time (ms)	102 (7)	128 (18)	<.001
Flight time (ms)	129 (12)	116 (9)	<.001

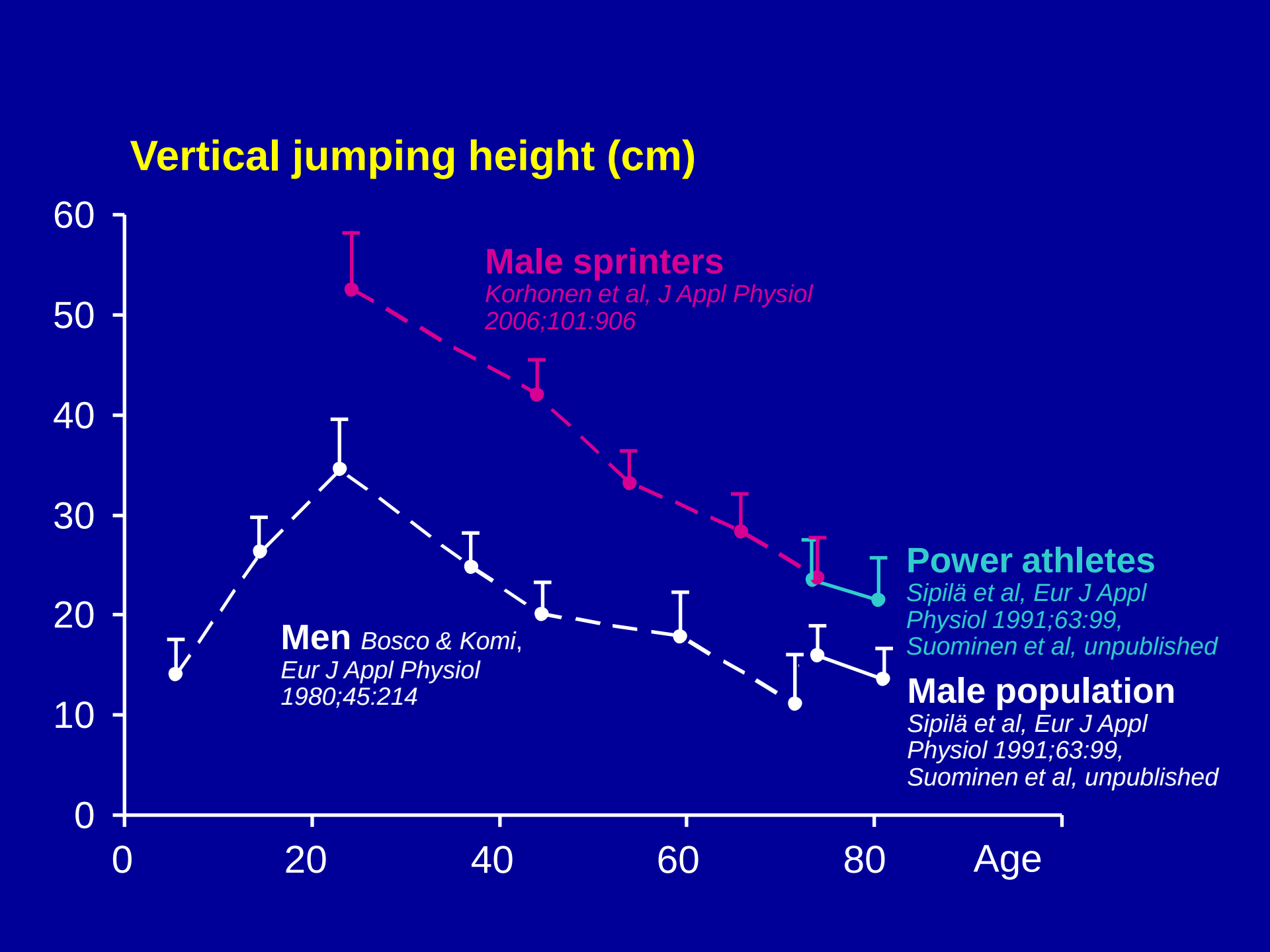
Korhonen et al, J Appl Biomech 2010;26:357


Maximal isometric force (N)
Male sprinters
Korhonen et al, J Appl Physiol 2006;101:906
Non-athletes
Häkkinen et al, JAPA 1998;6:232
4000
3000
2000
1000
0
18-33
40-49
50-59
60-69
70-84
Age

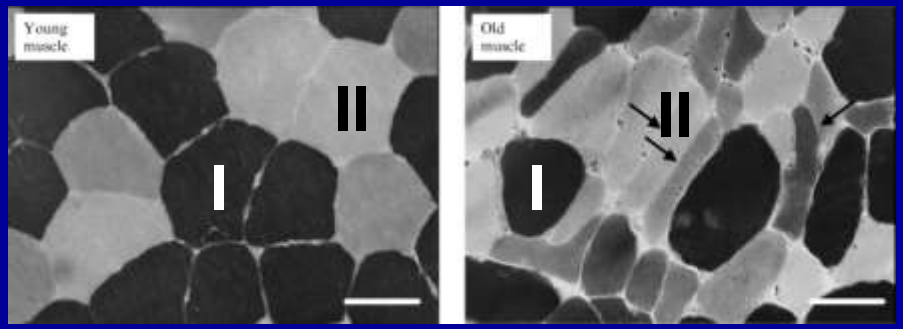
Normalised force-time curves and rate of force development in fast isometric leg extension in sprinters in different age groups



Korhonen et al, J Appl Physiol 2006;101:906

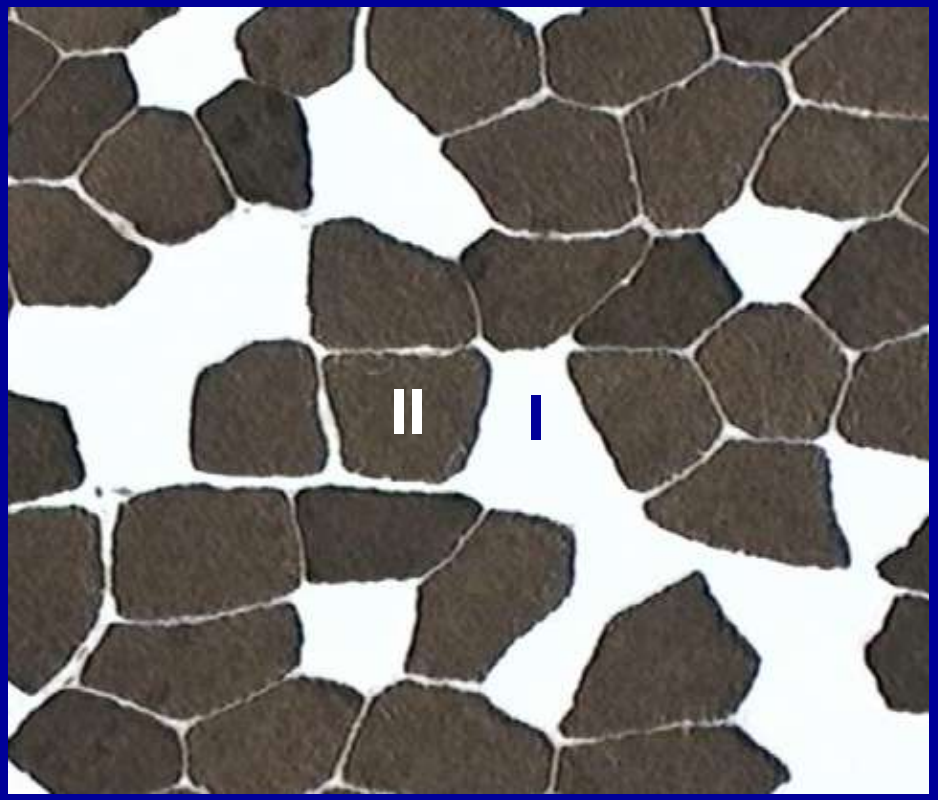

Vertical jumping height (cm)
60
50
40
30
20
10
0
0
20
40
60
80
Age
Male sprinters
Korhonen et al, J Appl Physiol 2006;101:906
Men Bosco & Komi, Eur J Appl Physiol 1980;45:214
Power athletes
Sipilä et al, Eur J Appl Physiol 1991;63:99, Suominen et al, unpublished
Male population
Sipilä et al, Eur J Appl Physiol 1991;63:99, Suominen et al, unpublished

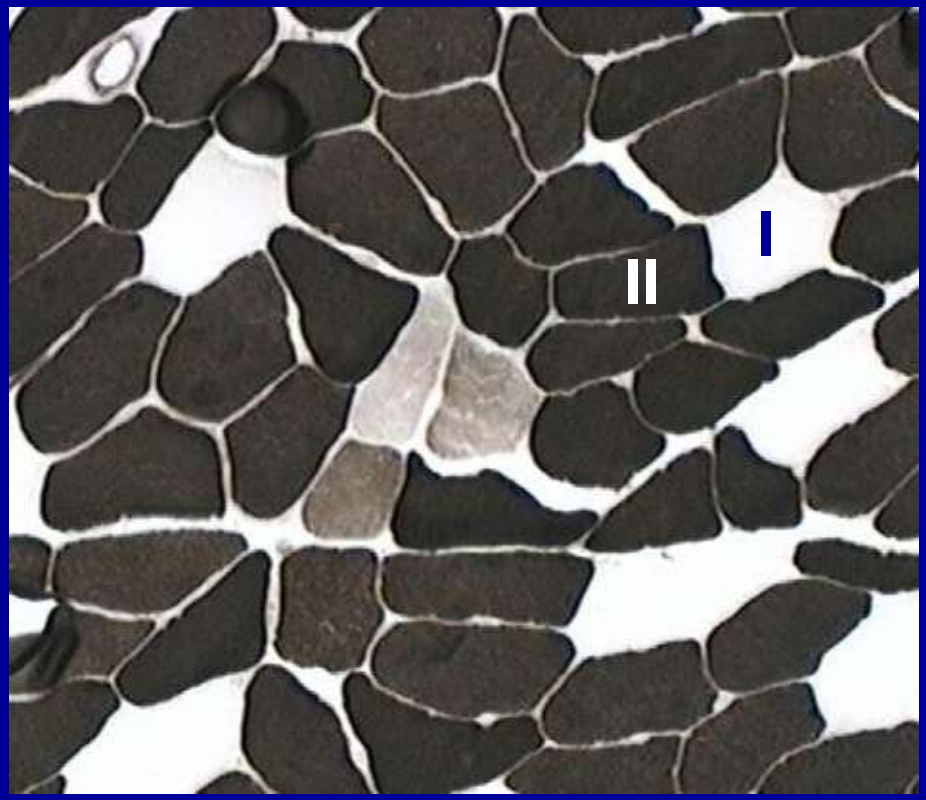
Young muscle



Old muscle

Andersen, Scand J Med Sci Sports 2003;13:40



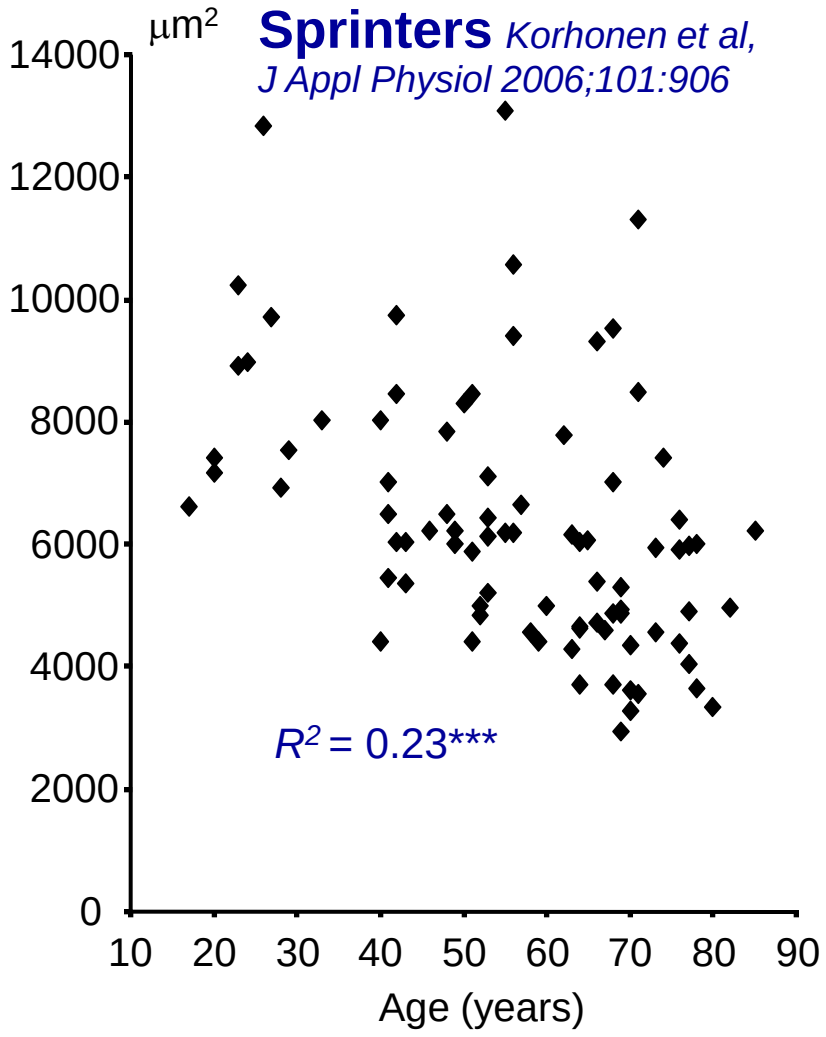


40-year-old sprinter

Korhonen et al, J Appl Physiol 2006;101:906

75-year-old sprinter

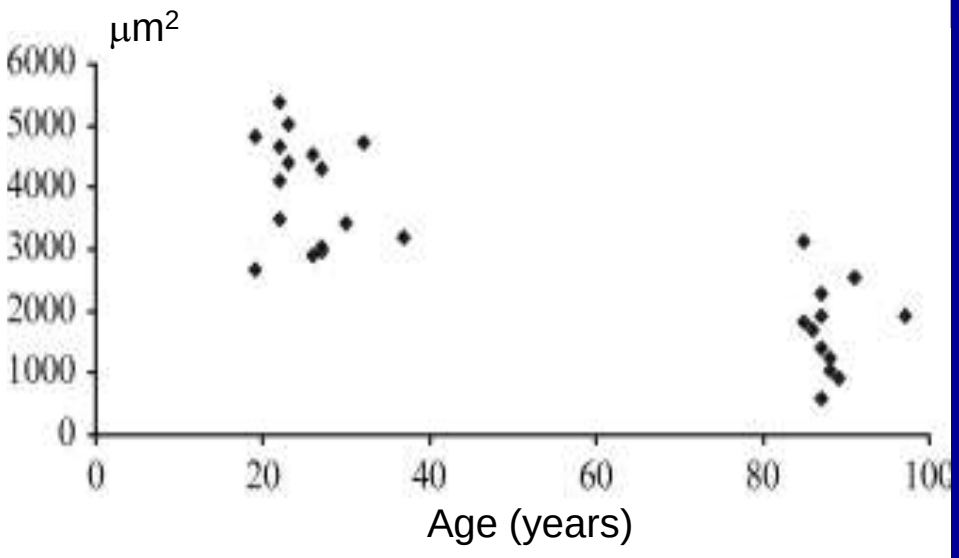
Type II fibre size



Sprinters *Korhonen et al, J Appl Physiol 2006;101:906*

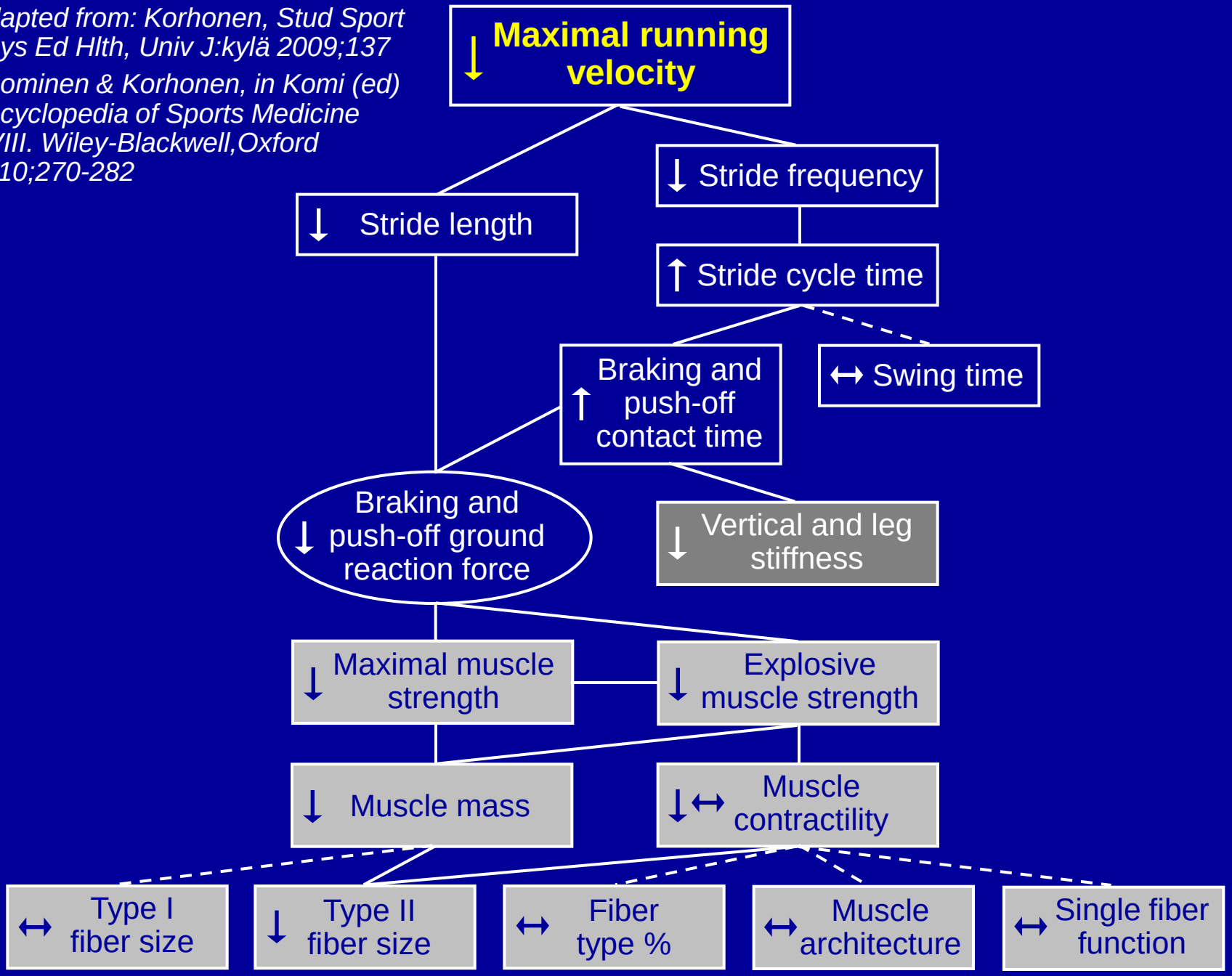
Untrained subjects

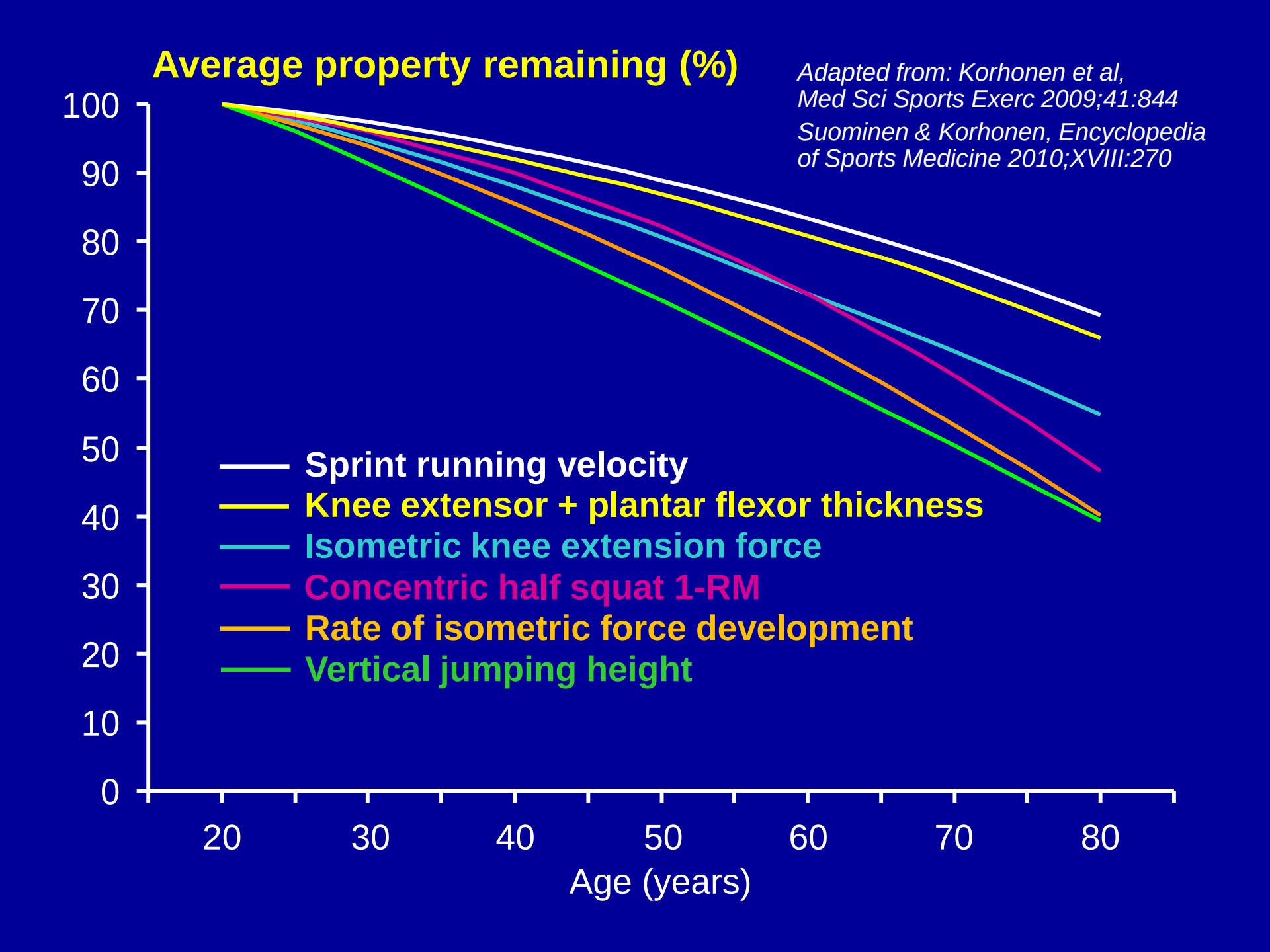
Andersen, Scand J Med Sci Sports 2003;13:40

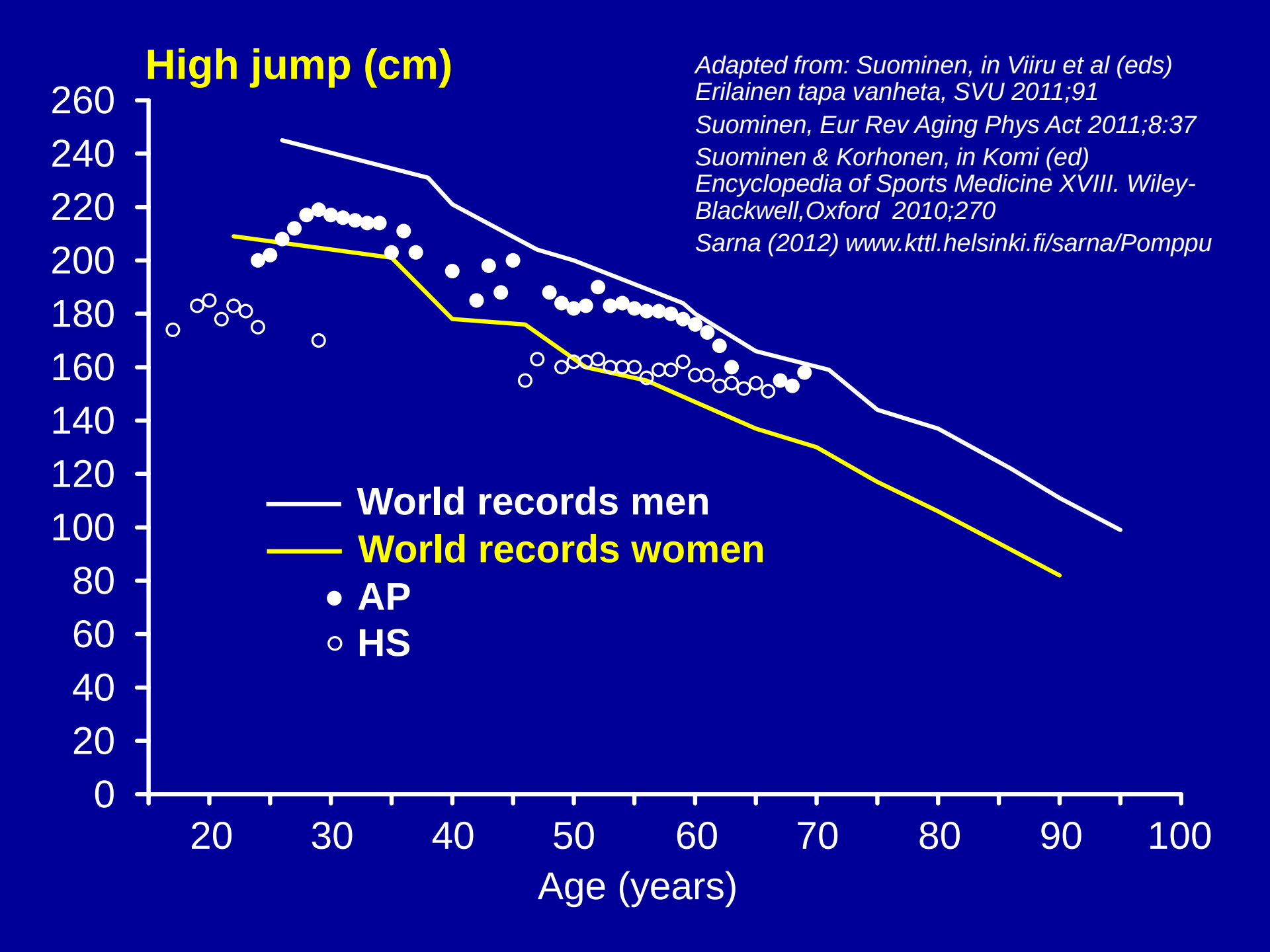


Adapted from: Korhonen, Stud Sport Phys Ed Hlth, Univ J:kylä 2009;137

Suominen & Korhonen, in Komi (ed) Encyclopedia of Sports Medicine XVIII. Wiley-Blackwell,Oxford 2010;270-282

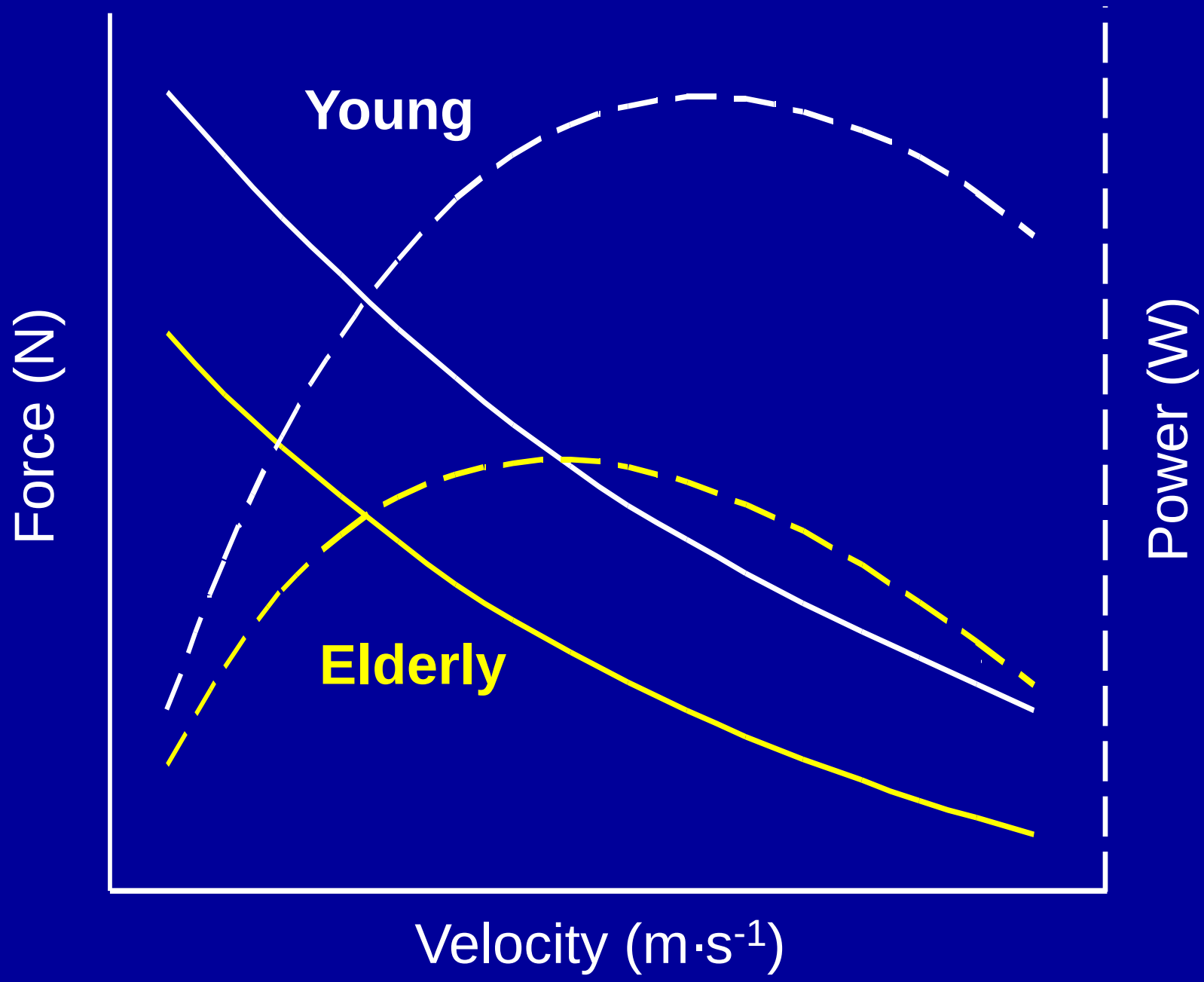


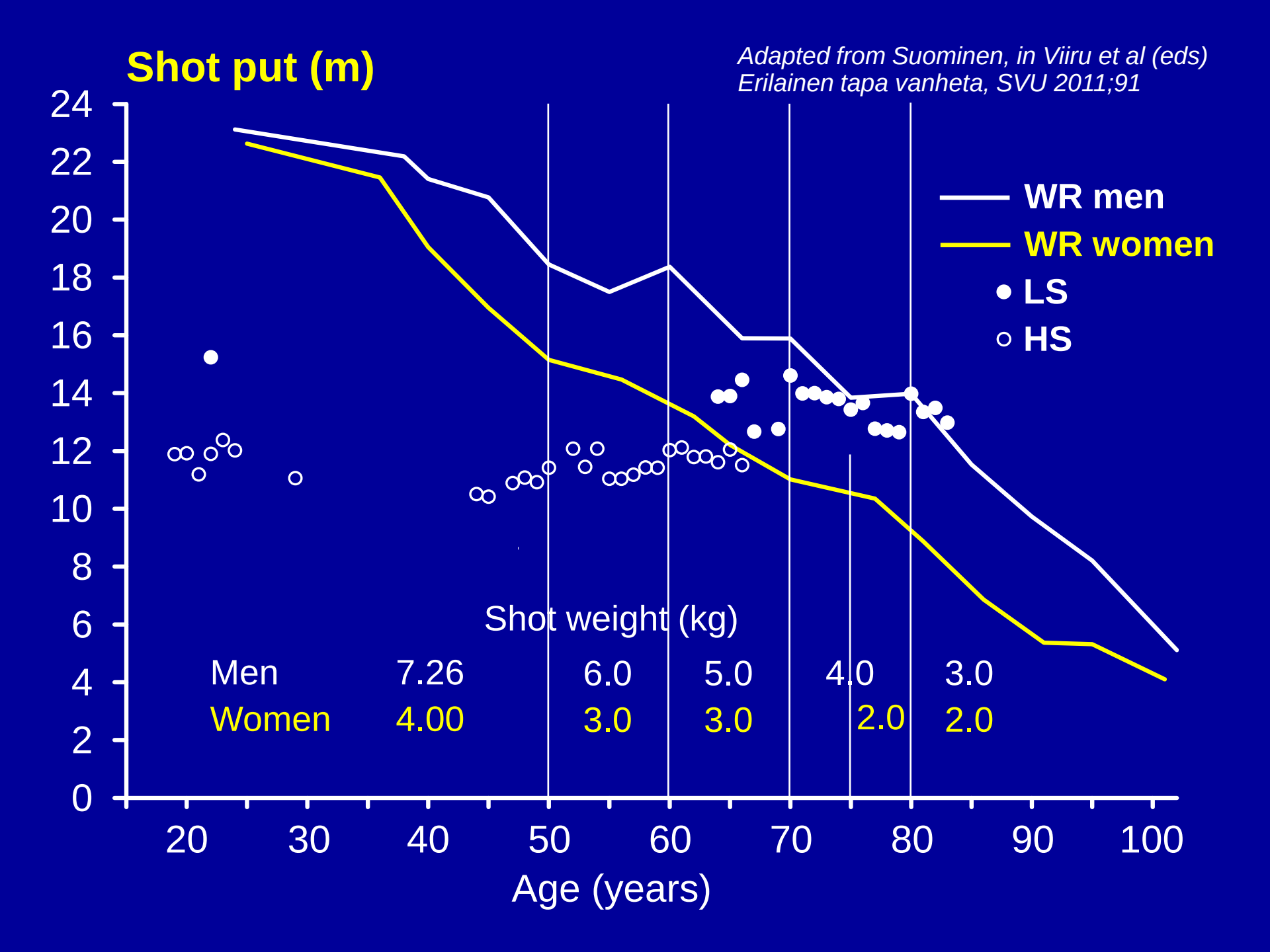

Average property remaining (%)
Adapted from: Korhonen et al, Med Sci Sports Exerc 2009;41:844
Suominen & Korhonen, Encyclopedia of Sports Medicine 2010;XVIII:270
100
90
80
70
60
50
40
30
20
10
0
20
30
40
50
60
70
80
Age (years)
Sprint running velocity
Knee extensor + plantar flexor thickness
Isometric knee extension force
Concentric half squat 1-RM
Rate of isometric force development
Vertical jumping height


High jump (cm)
Adapted from: Suominen, in Viiru et al (eds) Erilainen tapa vanheta, SVU 2011;91
Suominen, Eur Rev Aging Phys Act 2011;8:37
Suominen & Korhonen, in Komi (ed) Encyclopedia of Sports Medicine XVIII. Wiley-Blackwell,Oxford 2010;270
Sarna (2012) www.kttl.helsinki.fi/sarna/Pomppu
260
240
220
200
180
160
140
120
100
80
60
40
20
0
World records men
World records women
AP
HS
20
30
40
50
60
70
80
90
100
Age (years)

Remarks

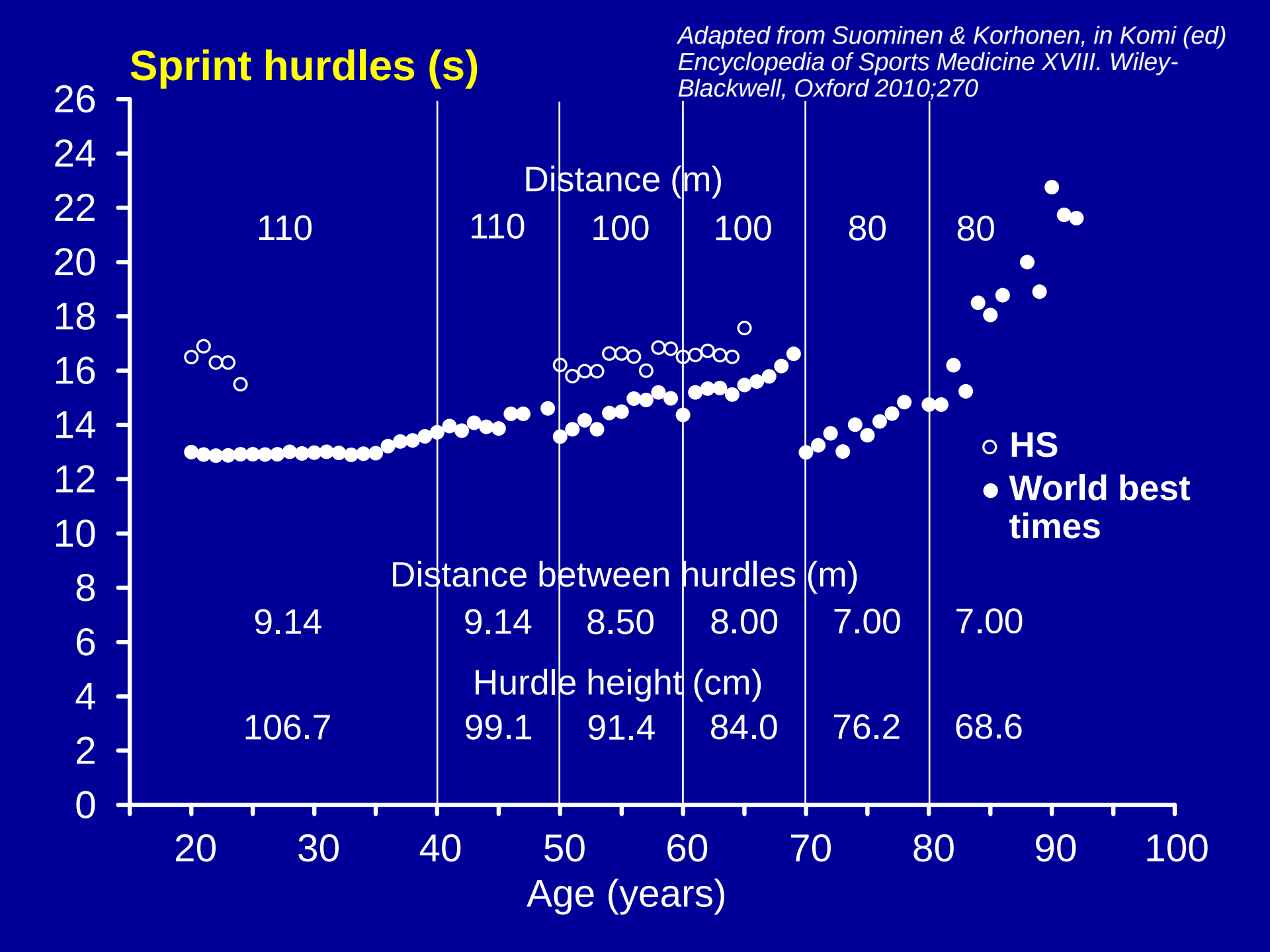
- The decline in performance looks steeper already in middle age and more linear throughout the age range than that shown for running speed in the previous examples
- This may, in part, be due to the more complex mixture of strength, power, flexibility, and technical skill needed in the high jump than in events such as sprint running
- Differences in competitive status, training volume and intensity, and the use of different jumping technique by the younger compared to older athletes also play a role
- In the absence of injuries or major changes in training, longitudinal data indicate a smaller age-related decline
- Moderate training status and level of performance in adult-hood makes it possible, at least for some time, to postpone the age-related decline or even to improve performance


Young
Elderly
Force (N)
Power (W)
Velocity (m·s-1)


Shot put (m)
Adapted from Suominen, in Viiru et al (eds)
Erilainen tapa vanheta, SVU 2011;91
WR men
WR women
LS
HS
Shot weight (kg)
Men 7.26 6.0 5.0 4.0 3.0
Women 4.00 3.0 3.0 2.0 2.0
Age (years)
0 2 4 6 8 10 12 14 16 18 20 22 24
20 30 40 50 60 70 80 90 100

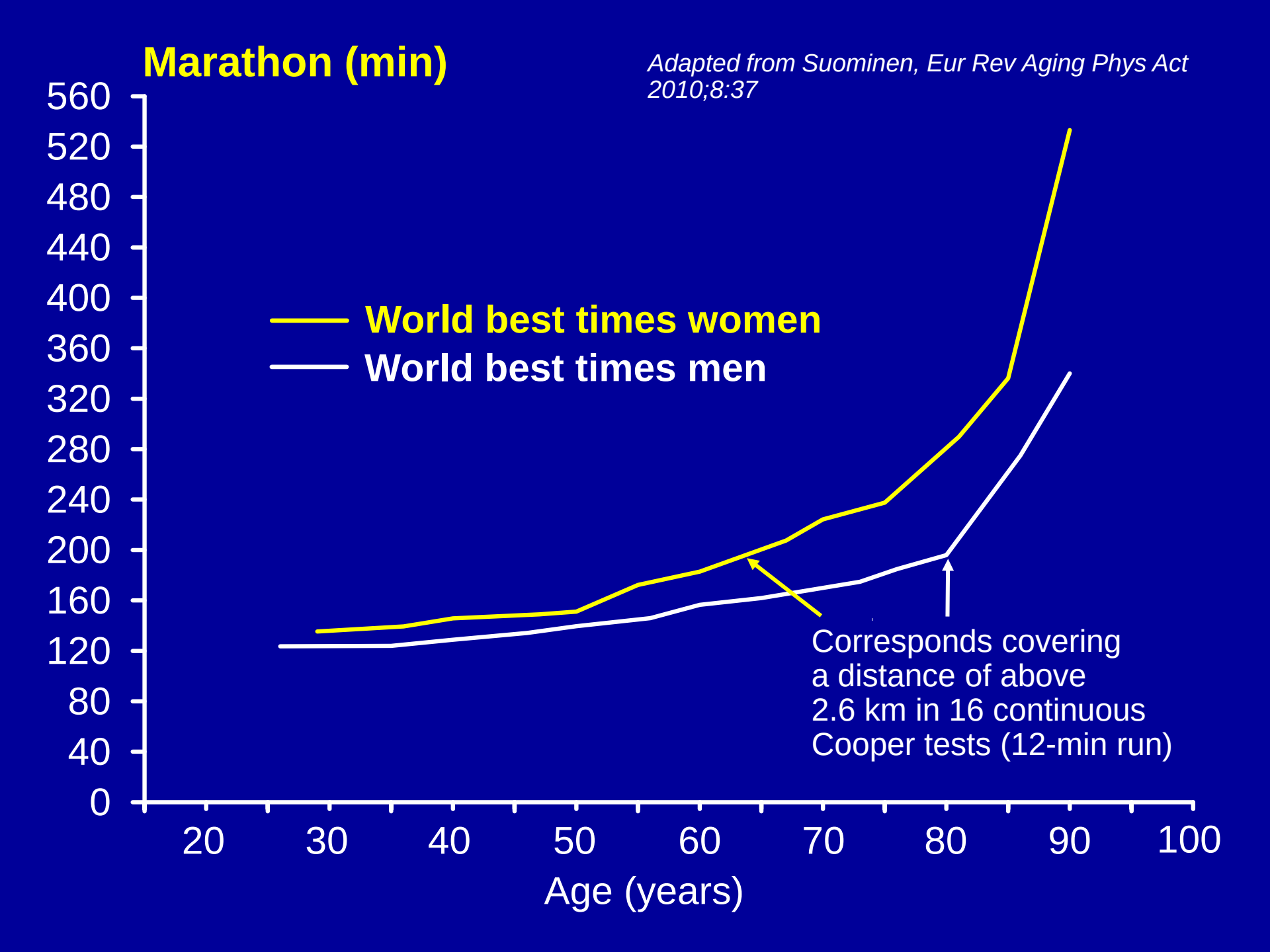
Remarks

- The relative decline in throwing events such as shot put look similar to those in high jump, even though the shot weight is lower in the older age categories
- Top performance in shot put requires a lot of whole body strength and power, the prerequisite of which is sufficient muscle mass
- Consequently, the sex differences also are more evident in throwing vs. running and jumping events
- As with other events, the cohort differences in training, event technique, and earlier level of performance over-estimate the age-related decline when compared to individual longitudinal data

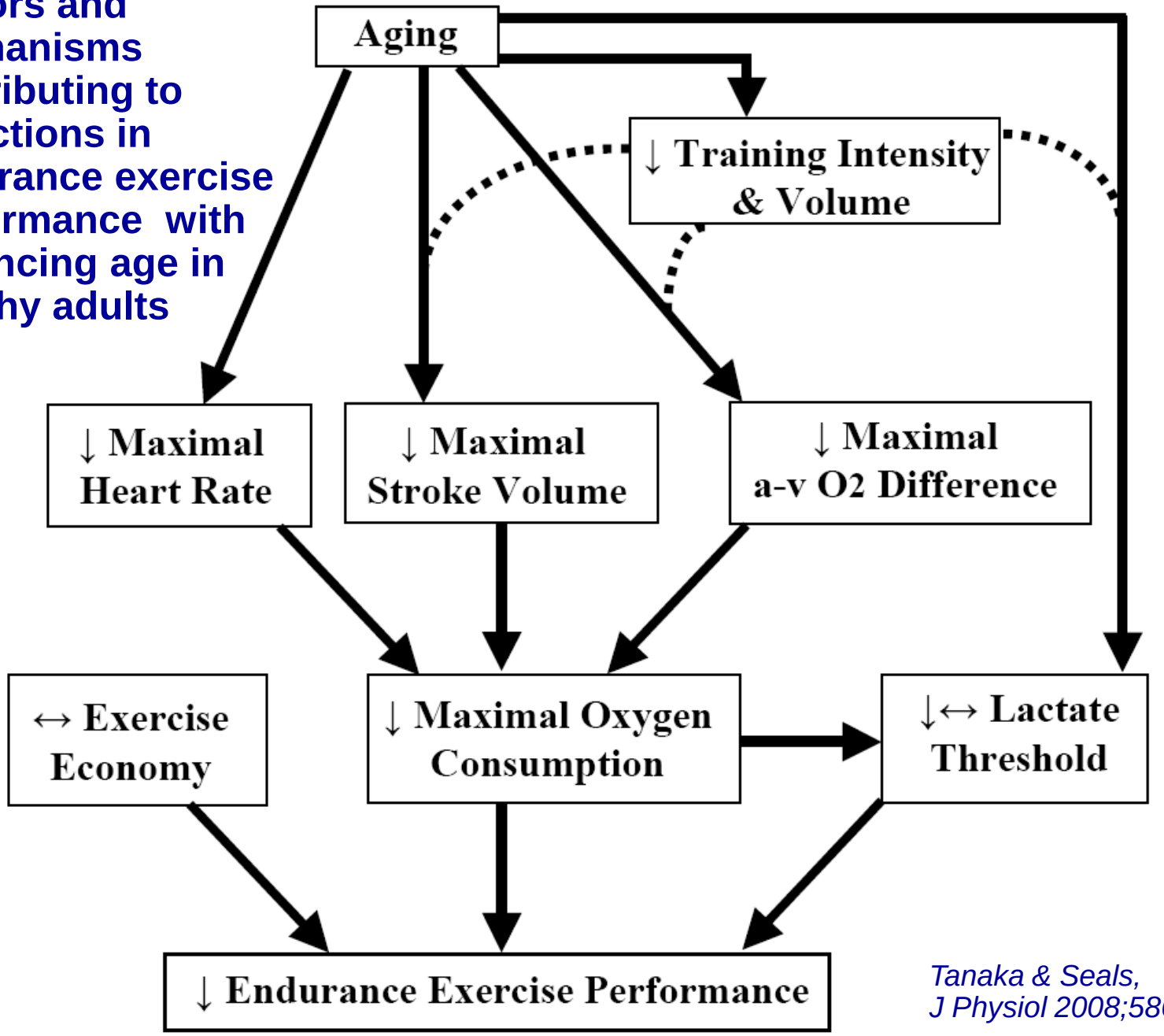

Sprint hurdles (s)
Adapted from Suominen & Korhonen, in Komi (ed) Encyclopedia of Sports Medicine XVIII. Wiley-Blackwell, Oxford 2010;270
26
24
22
20
18
16
14
12
10
8
6
4
2
0
Distance (m)
110
110
100
100
80
80
HS
World best times
Distance between hurdles (m)
9.14
9.14
8.50
8.00
7.00
7.00
Hurdle height (cm)
106.7
99.1
91.4
84.0
76.2
68.6
20
30
40
50
60
70
80
90
100
Age (years)

Remarks

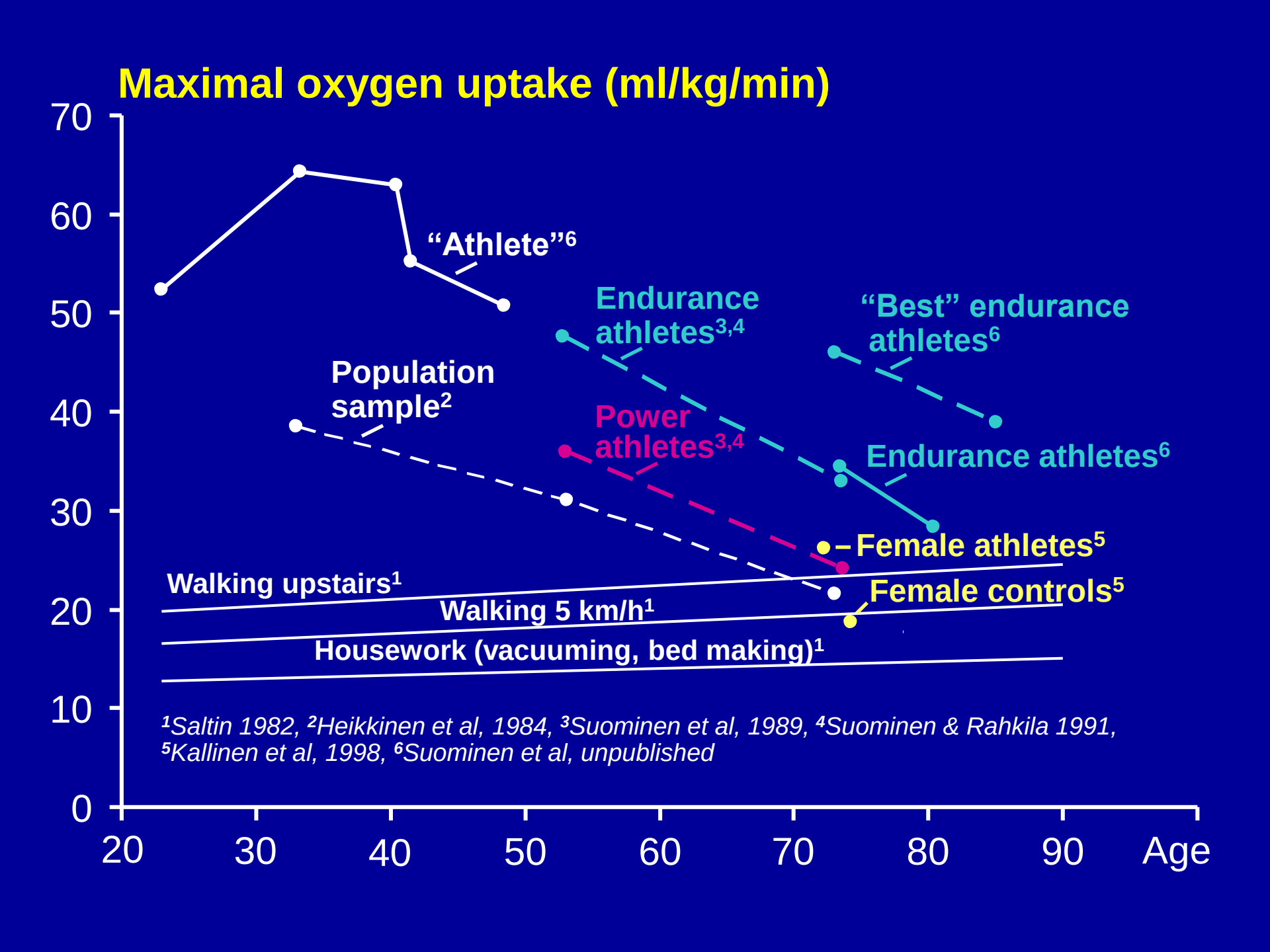
- Hurdling is a combination of a running race and a field event that demands high speed along with a highly refined technique on the part of the athlete
- Consequently, an event specific performance would be very difficult for the older age groups unless appropriate modifications to the event were made
- The event remains demanding, but the competitors may be motivated by anticipating success in the future age categories such as 50 and 70 years, where hurdling is made easier, thus enabling them to complete the race in about the same time as earlier
- Once again, individual longitudinal data indicate better maintenance of performance with ageing


Marathon (min)
Adapted from Suominen, Eur Rev Aging Phys Act 2010;8:37
560
520
480
440
400
360
320
280
240
200
160
120
80
40
0
World best times women
World best times men
Corresponds covering a distance of above 2.6 km in 16 continuous Cooper tests (12-min run)
20
30
40
50
60
70
80
90
100
Age (years)

Factors and mechanisms contributing to reductions in endurance exercise performance with advancing age in healthy adults

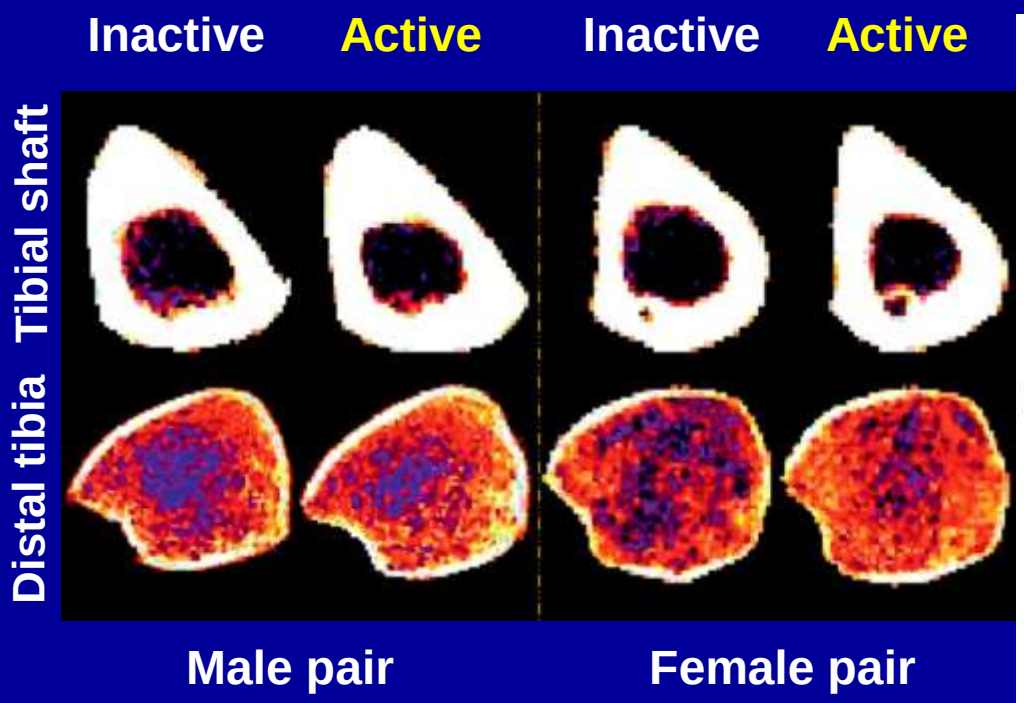


Tanaka & Seals, J Physiol 2008;586:55

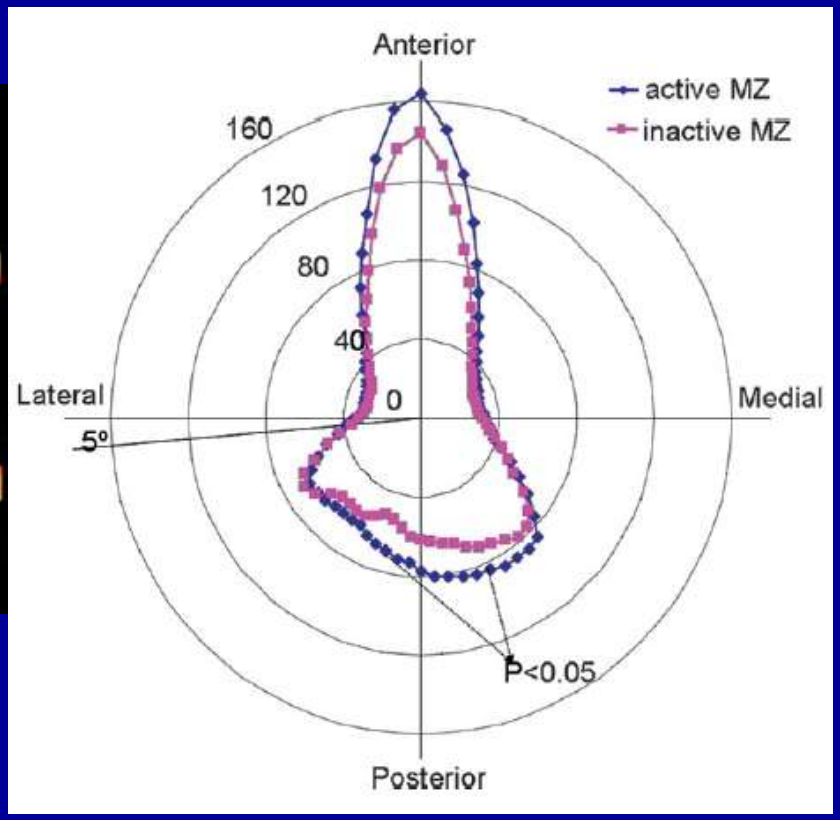

Maximal oxygen uptake (ml/kg/min)
70
60
50
40
30
20
10
0
20
30
40
50
60
70
80
90
Age
"Athlete"6
Endurance athletes3,4
"Best" endurance athletes6
Population sample2
Power athletes3,4
Endurance athletes6
Female athletes5
Female controls5
Walking upstairs1
Walking 5 km/h1
Housework (vacuuming, bed making)1
1Saltin 1982, 2Heikkinen et al, 1984, 3Suominen et al, 1989, 4Suominen & Rahkila 1991, 5Kallinen et al, 1998, 6Suominen et al, unpublished

Remarks

- The record performances in marathon do not dramatically deteriorate until 75 to 80 years of age
- Although the age-related decline in aerobic capacity in endurance athletes resembles that in untrained persons, this decline cannot be solely attributed to aging, as these athletes also reduce their training intensity and volume
- On the other hand, the age-related decline in controls may be biased in that the subjects tested in the oldest age groups probably represent individuals with better health and fitness than the average sedentary population
- It is also noteworthy that, where the slopes of the decline are similar, the relative difference in aerobic capacity between endurance athletes and non-athletes is actually greater with ageing.
-



Long-term leisure time physical activity improves/maintains bone strength in a site-specific manner: thicker cortex and higher bending strength in the tibial shaft and higher trabecular density and compressive strength in the distal tibia



Polar mass distribution of tibial shaft in middle-aged active and inactive MZ twin pairs discordant for physical activity

Ma H, Leskinen T, Alen M, Cheng S, Sipilä S, Heinonen A, Kaprio J, Suominen H, Kujala UM. J Bone Miner Res 2009;24:1427

Sprinter studies

- Sprint-trained athletes as a model for musculo-skeletal effects of “primary” ageing and exercise
- Effects of combined strength and sprint training on the structure and function of skeletal muscle and bone

Master sprinters
40-85-yr-old men
(n=83)

Young sprinters
18-33-yr-old men
(n=25)

Experimental (n=40)
6-month training programme (muscle hypertrophy → maximal/explosive strength → speed)

Control (n=32)
Own training

Korhonen et al, J Appl Physiol 2006;101:906

Cristea, Korhonen et al, Acta Physiol 2008;193:275

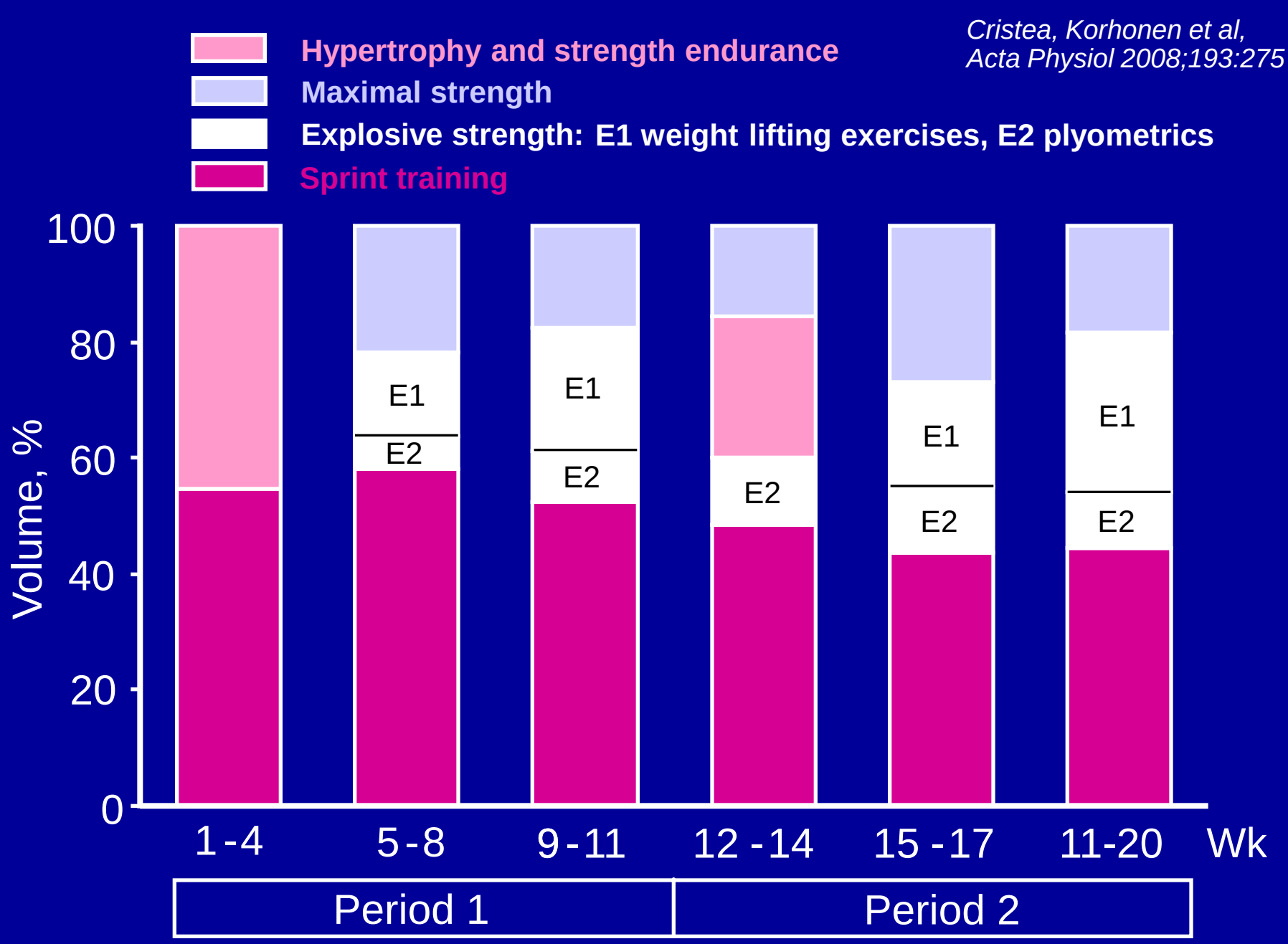
Korhonen et al, Med Sci Sports Exerc 2009;41:844

Suominen & Korhonen, in Komi (ed) Encyclopedia of Sports Medicine XVIII. Wiley-Blackwell,Oxford 2010;270

Physical characteristics of male sprinters

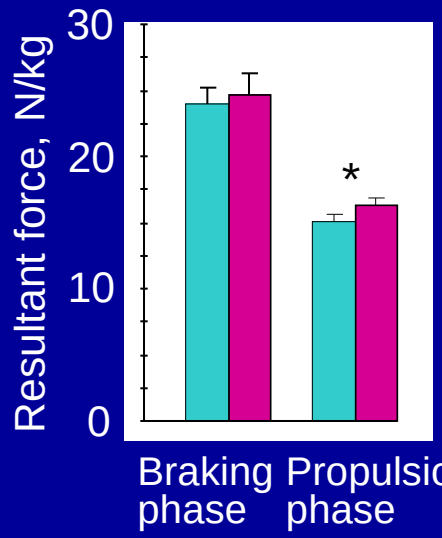
	18-33-yr (n=16)	**40-64-yr** (n=35-41)	**65-85-yr** (n=35-42)	*p*
Age (yrs)	24.3 (3.9)	53.5 (6.8)	74.5 (7.4)	
Height (cm)	178.0 (4.3)	177.1 (6.5)	170.9 (5.1)	<0.001
Weight (kg)	77.2 (5.4)	75.6 (7.8)	70.7 (7.1)	0.001
Years of training	13.2 (5.0)	28.7 (11.6)	35.3 (19.5)	<0.001
Training (times/wk)	5.9 (1.2)	4.4 (1.2)	4.1 (1.3)	<0.001
Training (h/wk)	11.5 (2.3)	6.8 (2.9)	6.1 (2.9)	<0.001
Strength training (h/wk)	**5.2 (1.5)**	**1.5 (1.5)**	**0.8 (0.8)**	<0.001

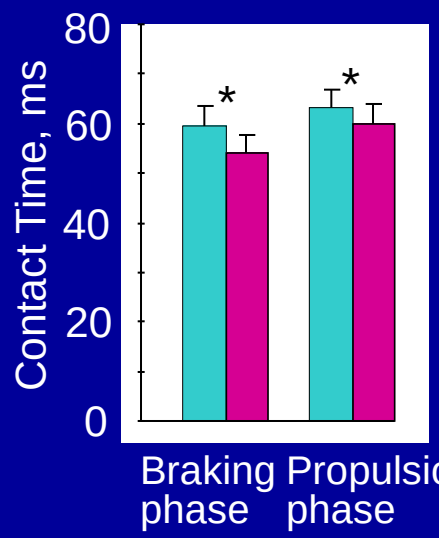
Korhonen et al, J Appl Physiol 2006;101:906

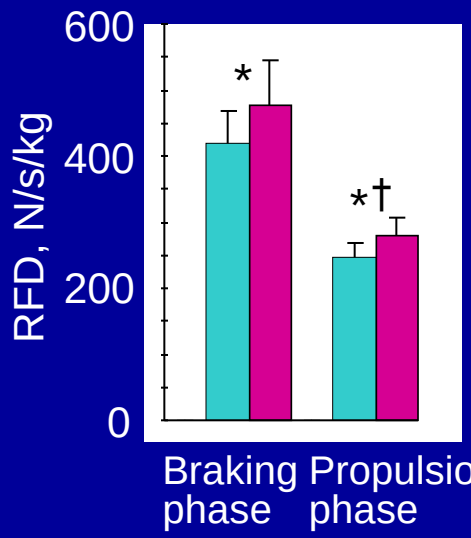

Hypertrophy and strength endurance
Maximal strength
Explosive strength: E1 weight lifting exercises, E2 plyometrics
Sprint training
Cristea, Korhonen et al,
Acta Physiol 2008;193:275
Volume, %
100
80
60
40
20
0
E1
E2
E1
E2
E2
E1
E2
E1
E2
1 - 4
5 - 8
9 - 11
12 - 14
15 - 17
11-20
Wk
Period 1
Period 2

Experimental group

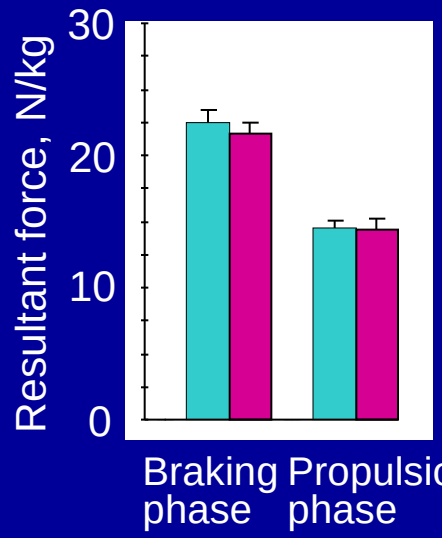
Cristea, Korhonen et al, Acta Physiol 2008;193:275

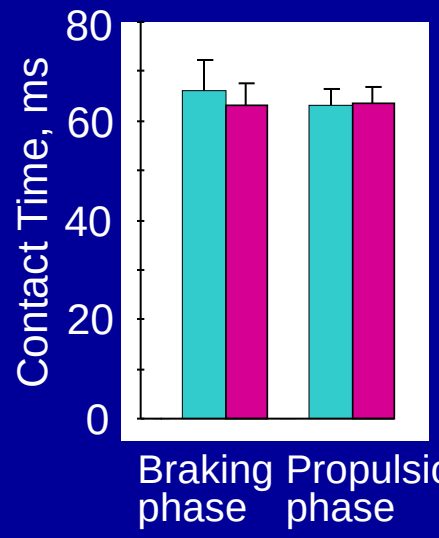


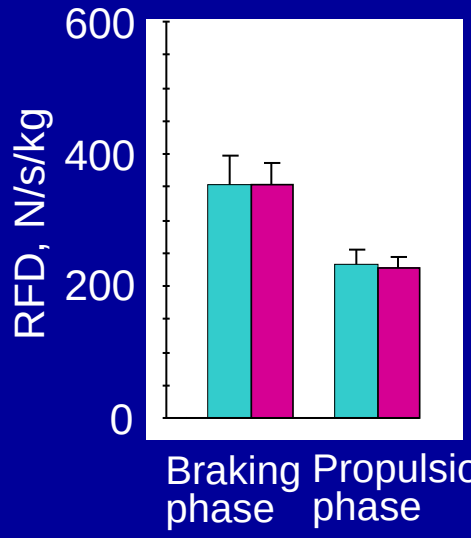




Control group







Baseline

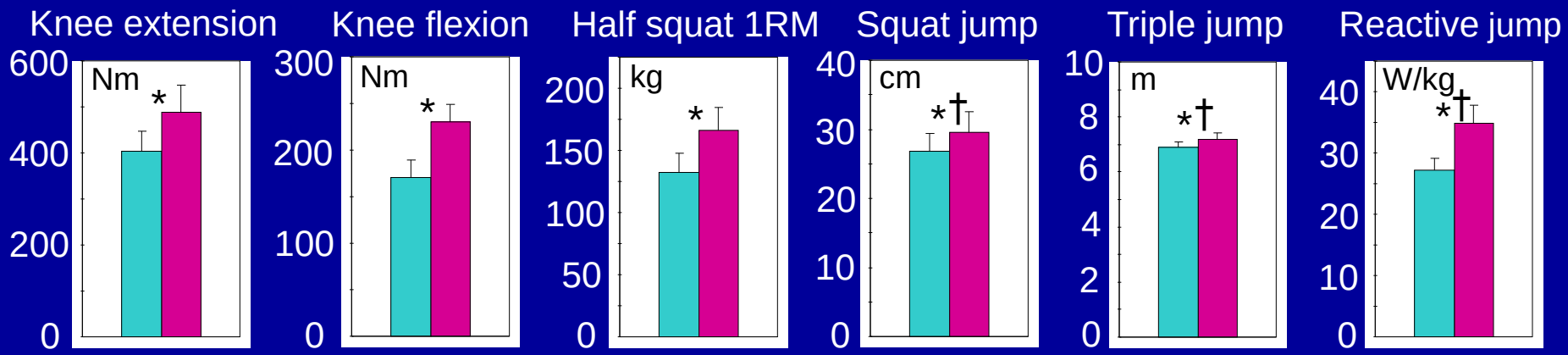
6-month

* $p<0.05$ baseline vs. 6-month

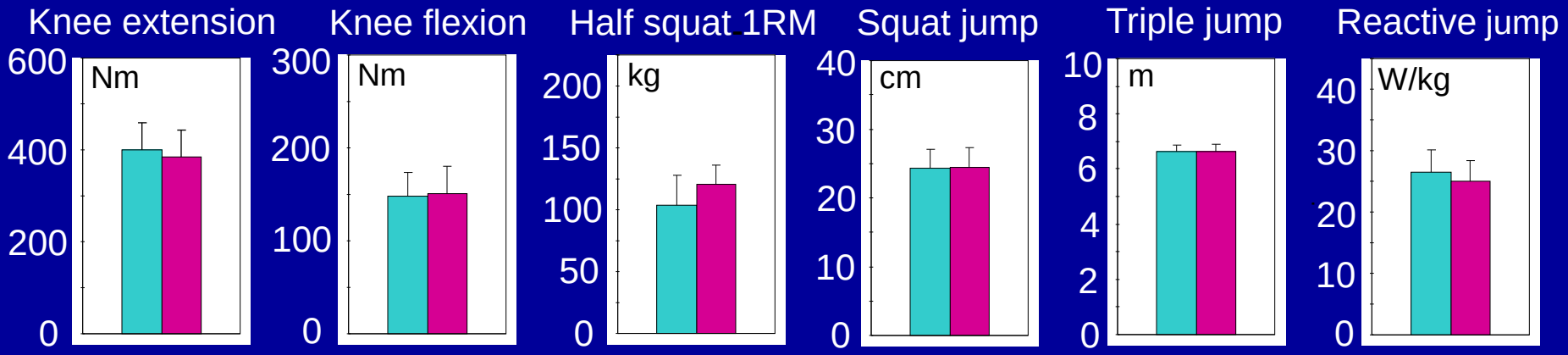
† $p<0.05$ change in experimental vs. control group

Cristea, Korhonen et al,
Acta Physiol 2008;193:275

Experimental group



Control group



Baseline
6-month

* $p<0.05$ baseline vs. 6-month
† $p<0.05$ change in experimental vs. control group

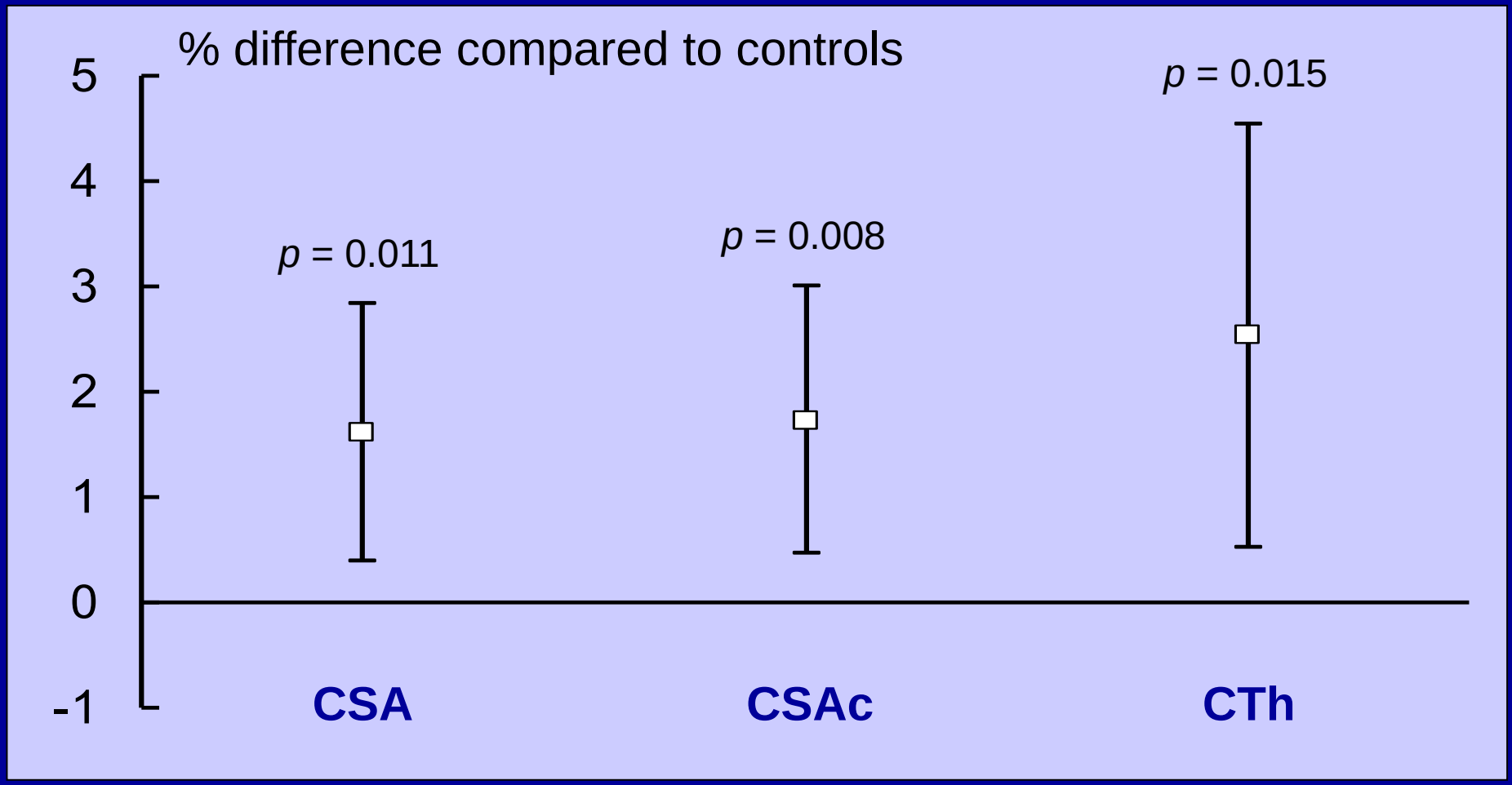
Effect of strength and speed training on contractile function of single muscle fibres in male master sprinters (Mean, SD)

	Type I			Type IIa		
	CSA (μm^2)	ST (N/cm^2)	V_o (ML/s)	CSA (μm^2)	ST (N/cm^2)	V_o (ML/s)
Experimental Baseline	3000±190 (*n*=90)	30.9±3.4	0.50±0.06 (*n*=45)	2810±240 (*n*=44)	33.9±5.2	1.74±0.19 (*n*=21)
Experimental 6-month	3670±390 (*n*=85)	30.2±3.3	0.61±0.05 (*n*=45)	**3950±360*** (*n*=47)	38.0±4.0	1.83±0.26 (*n*=28)
Control Baseline	3280±440 (*n*=25)	32.6±1.2	0.57±0.10 (*n*=15)	3320±500 (*n*=31)	33.0±5.9	1.58±0.14 (*n*=19)
Control 6-month	3350±560 (*n*=28)	30.3±6.6	0.57±0.16 (*n*=12)	3380±340 (*n*=31)	32.0±6.6	1.66±0.33 (*n*=15)

*$p<0.05$ baseline vs. 6-month

Cristea, Korhonen et al, Acta Physiol 2008;193:275

Master sprinters in the experimental group had increased tibial shaft cross-sectional area, cortical area, and cortical thickness after 6-month strength and speed training compared to control sprinters



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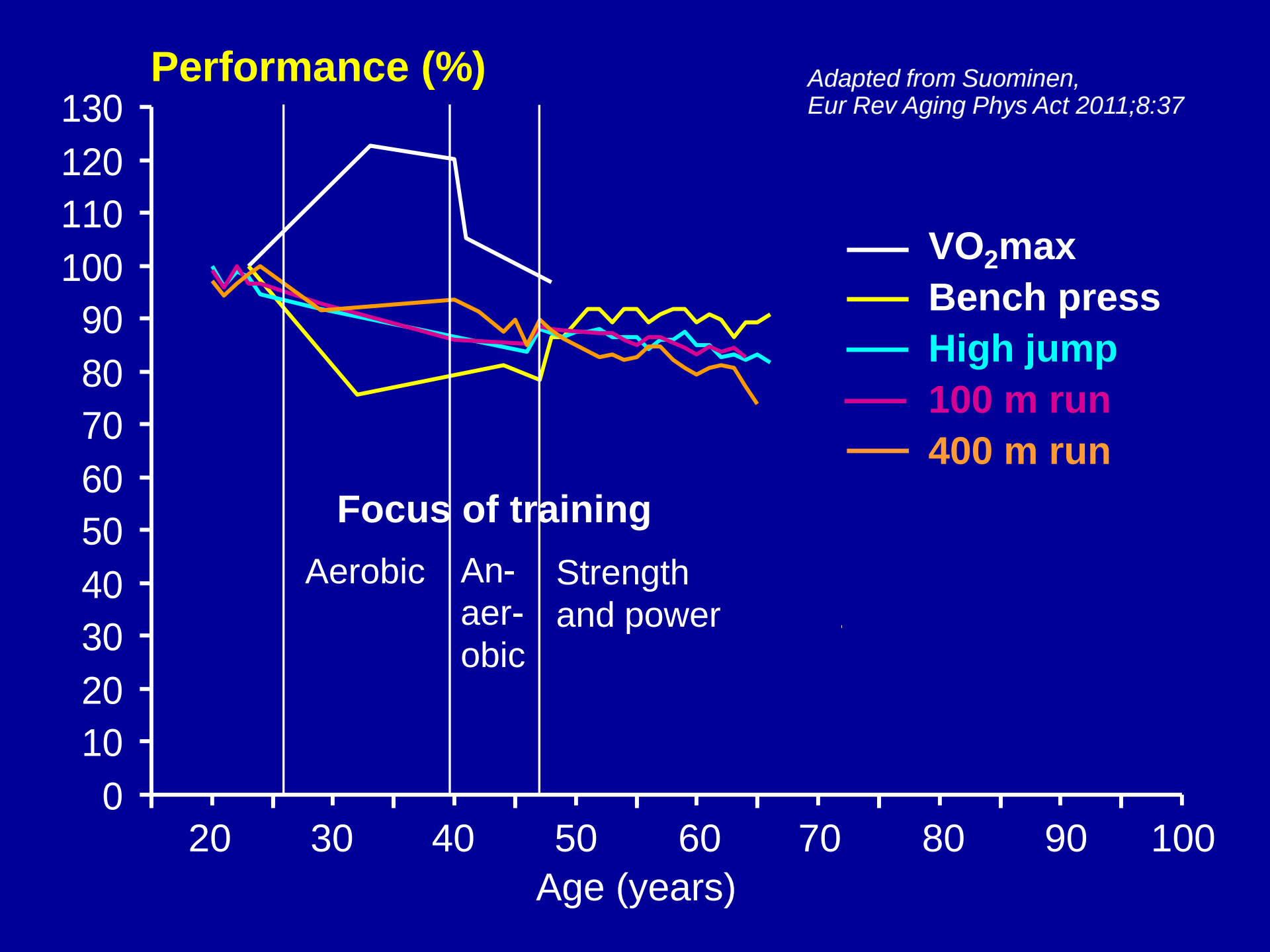
Performance (%)
130
120
110
100
90
80
70
60
50
40
30
20
10
0
20
30
40
50
60
70
80
90
100
Age (years)
Adapted from Suominen,
Eur Rev Aging Phys Act 2011;8:37
VO2max
Bench press
High jump
100 m run
400 m run
Focus of training
Aerobic
An-
aer-
obic
Strength
and power

Concluding remarks 1/2

- Elite master athletes with long-term devotion to intensive physical training are challenging present estimates of age-related changes in maximal physical performance
- Although a distinct age decrement remains, track and field records and sport-specific test results show that athletic performance may be preserved at an extraordinary high level well into old age
- Similarly, underlying capacities such as muscle strength, speed and endurance as well as bone mass and strength are maintained far above the age norms, thus providing superior functional reserves for activities of daily living
- Nevertheless, even the best records continue to over-estimate the “primary” or “inherent” age decrements.

Concluding remarks 2/2

- Plasticity of individual development is preserved in later life thus making it possible, at least for some time, to modify the age-associated decline in the different aspects of performance
- Although the intensive physical training practised by athletes is beyond the scope of most sedentary older populations, there is a lesson to be learned from the fortunate individuals with good physical inheritance, health habits, and motivation throughout the life-course
- Master athletes raise both physical and psychological ceilings and shatter the barriers of expectations that society has for the elderly

Recent references

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Research group and collaboration in the sprinter studies

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