IRONMAN WORLD CHAMPIONSHIP MEDICAL SYMPOSIUM

33rd Annual Ironman Sports Medicine Conference

Monday October 9th, 2023

Limits to Human Endurance Performance

Professor Gregory P Whyte OBE PhD DSc FBASES FACSM

Research Institute for Sport & Exercise Sciences
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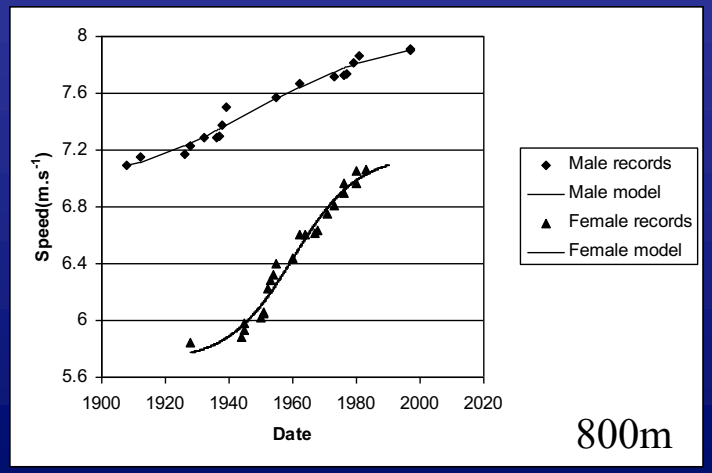
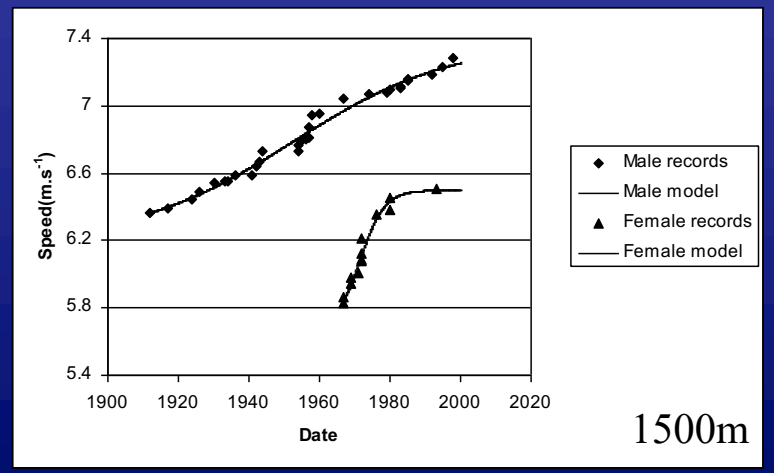
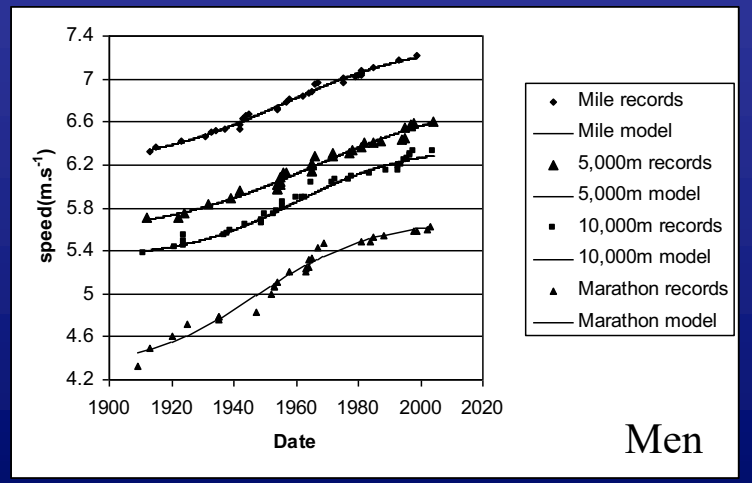
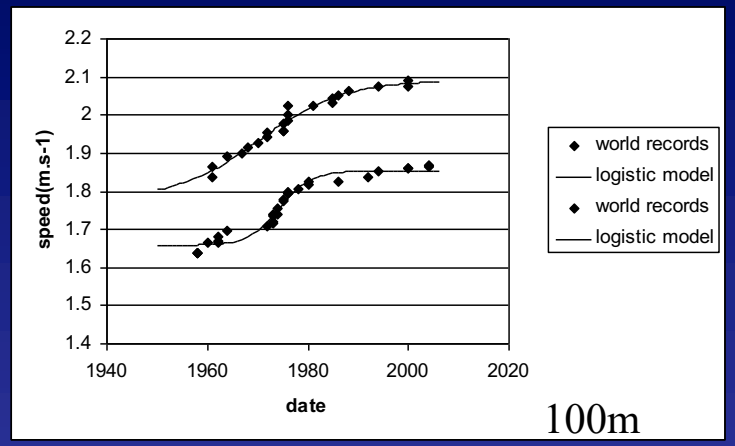
Limits to Human Performance

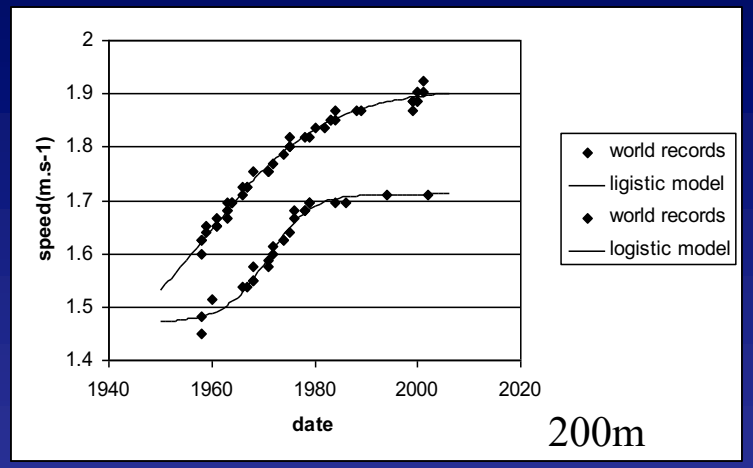


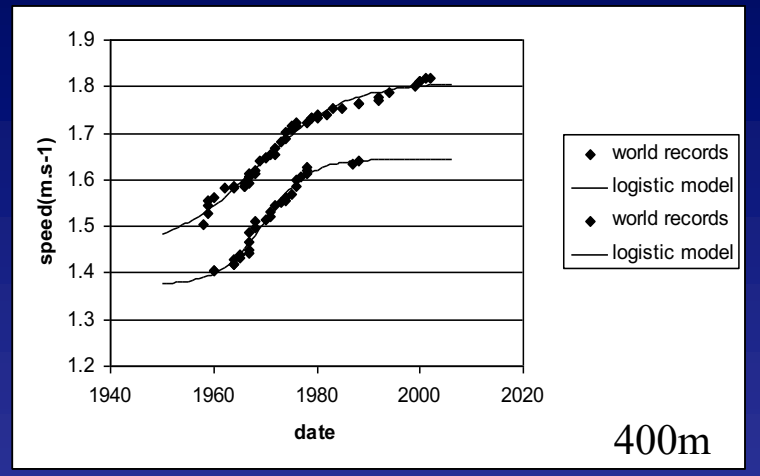




Nevill & Whyte *MSSE* 2005







Nevill, Whyte, Holder & Peyrebrune *IJSM* 2007

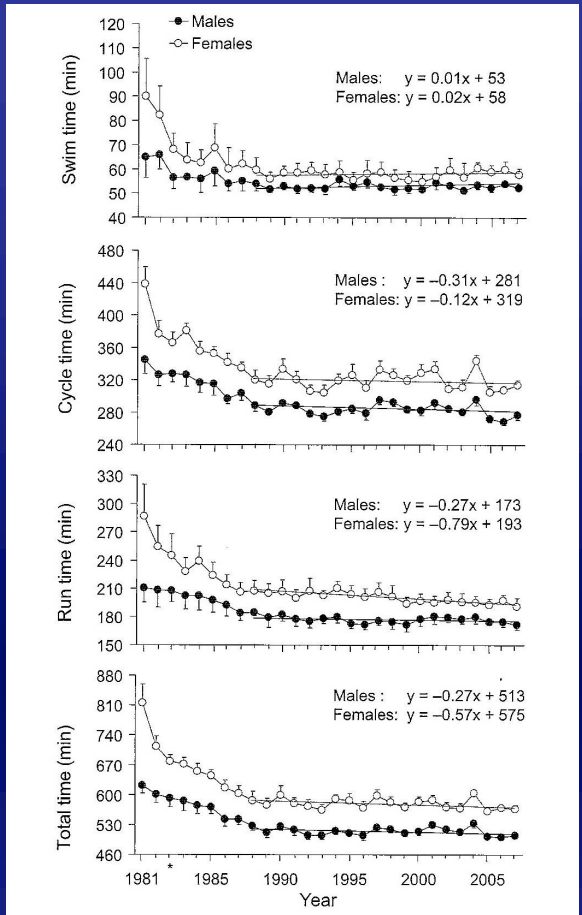


FIGURE 1—Swimming, cycling, running, and total performance times at the Hawaii Ironman Triathlon for the top 10 males and females from 1981 to 2007. Values are mean ± SD. *Two races took place in 1982 (February and October). Regression lines are presented from 1988 to 2007 in bold line for male and in dotted line for females. The equations are for the year 2008 as 0, so the intercept is the time in the year 2008. The slope of each equation indicates the change in time (min) performance per year since 1988.

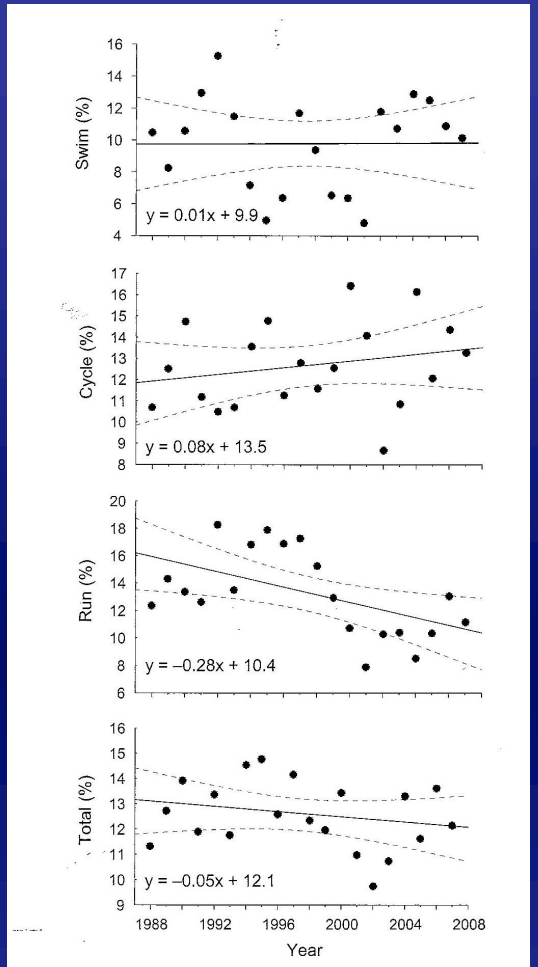


FIGURE 2—Gender differences in time for swimming, cycling running, and total times from 1988 to 2007. The lenticular curves represent the 95% CI for the predicted mean value. The equations ar for the year 2008 as 0, so the intercept is the time in the year 2008. The slope of each equation indicates the change in gender difference (%) per year since 1988.

Lepers, R. *MSSE* 2008;40(10):18281834.

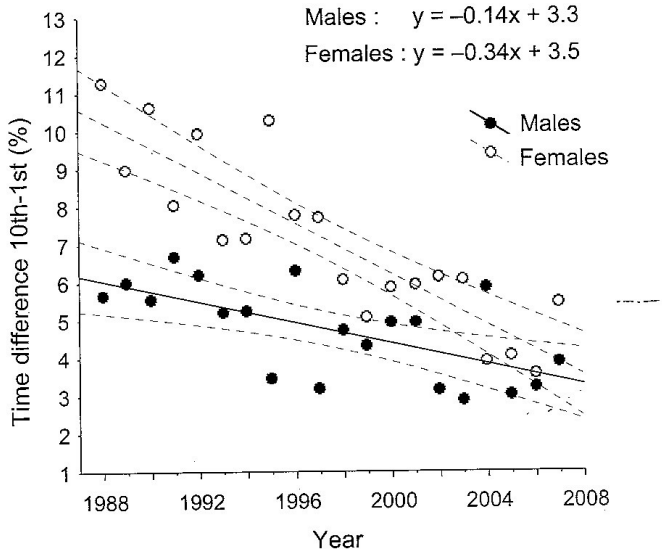


FIGURE 3—Time difference between the winner and the 10th placer expressed as a percentage of the winner time for both females and males over the 1988–2007 period. The lenticular curves represent the 95% CI for the predicted mean value. The equations are for the year 2008 as 0, so the intercept is the time in the year 2008. The slope of each equation indicates the change in time difference (%) between the winner and the 10th placer per year since 1988.

3.8km Swim Time (min)

	Hawaii Ironman Triathlon	Waikiki Rough Water Swim (Honolulu)	
Male	54.0 ± 0.2	49.6 ± 2.1	(8.9%)
Female	59.9 ± 3.4	54.4 ± 1.0	(10.1%)
Diff (%)	10.9	9.7	

42.2km Run Time (min)

	Hawaii Ironman Triathlon	New York Marathon	
Male	174.4 ± 4.8	131.1 ± 1.1	(33%)
Female	197.4 ± 6.0	148.9 ± 2.9	(32.6%)
Diff (%)	13.2	13.3	

Comparison of top 10 Hawaii Ironman Triathlon times and the top 10 specialist elite times for males and females in 2006

Lepers, R. *MSSE* 2008;40(10):18281834.

♂ Vs. ♀

Lower O_2 carrying capacity, smaller heart and lungs, higher adiposity result in a lower aerobic power in females, even when scaled for body mass and adiposity.

Lower absolute strength & power results in lower peak velocity in females.

Sociological Barriers

- Before the AAA men and women of all social classes ran for money
- AAA eliminated 'undesirables' who ran for money – 'professionals'

so that…

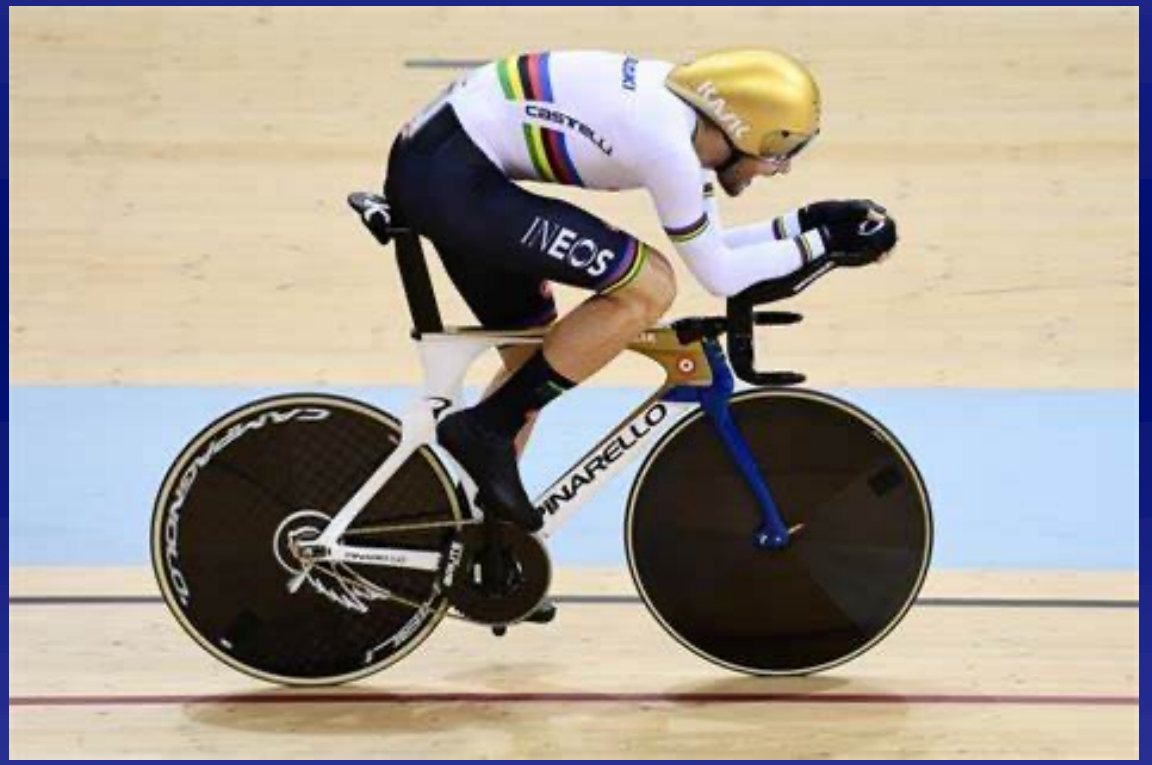
'Middle class men who wanted to take part in sport but were 'far from good enough to hold their own in professional company'.

Peter Radford, 2004

PSYCHOLOGICAL BARRIERS

TECHNOLOGICAL BARRIERS

World 1 Hour Record



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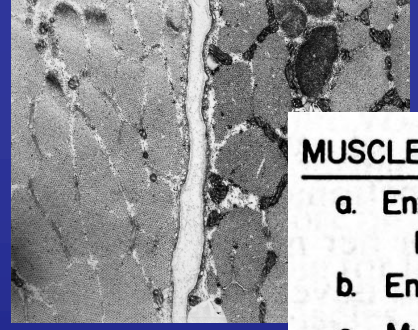
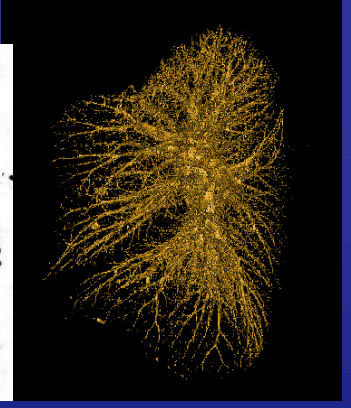


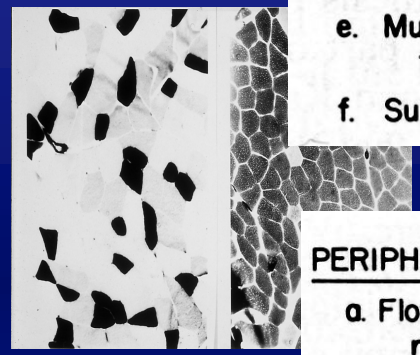
MUSCLE METABOLISM

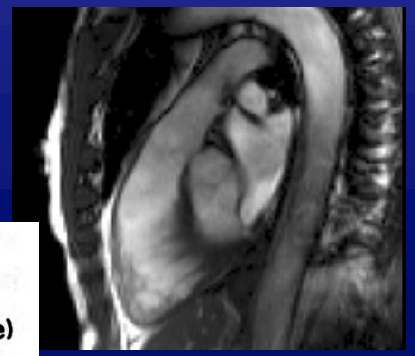
a. Enzymes and oxidative potential
b. Energy stores
c. Myoglobin
d. Mitochondria - size and number
e. Muscle mass and fiber type
f. Substrate delivery

RESPIRATION

a. O_2 diffusion
b. Ventilation
c. Alveolar ventilation: perfusion ratio
d. Hb - O_2 affinity





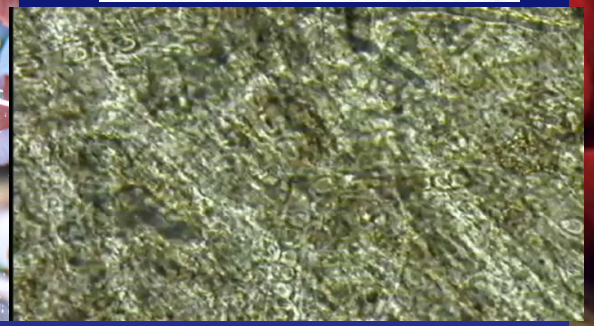


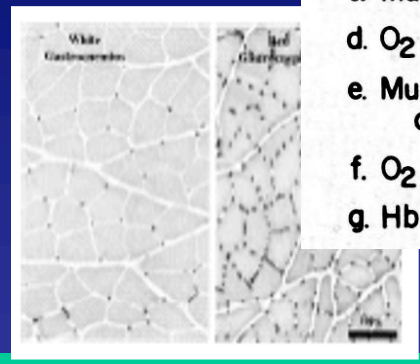
PERIPHERAL CIRCULATION

a. Flow to non-exercising regions
b. Muscle blood flow
c. Muscle capillary density
d. O_2 diffusion
e. Muscle vascular conductance
f. O_2 extraction
g. Hb - O_2 affinity

CENTRAL CIRCULATION

a. Cardiac output (heart rate, stroke volume)
b. Arterial blood pressure
c. Hb concentration

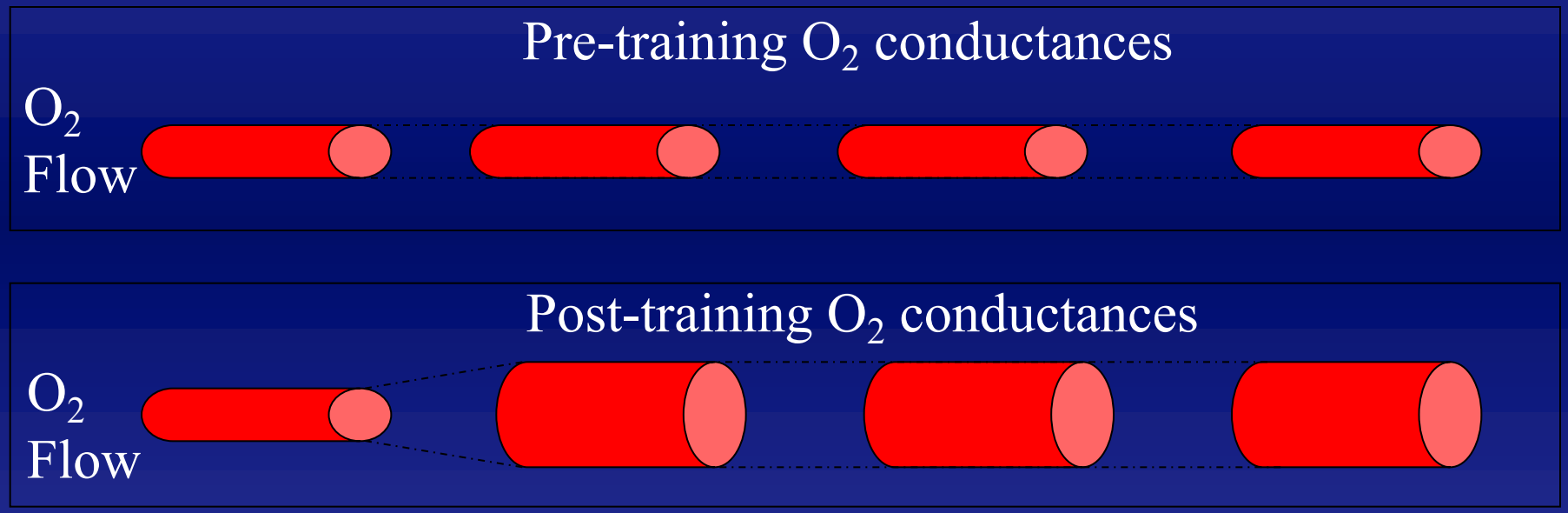




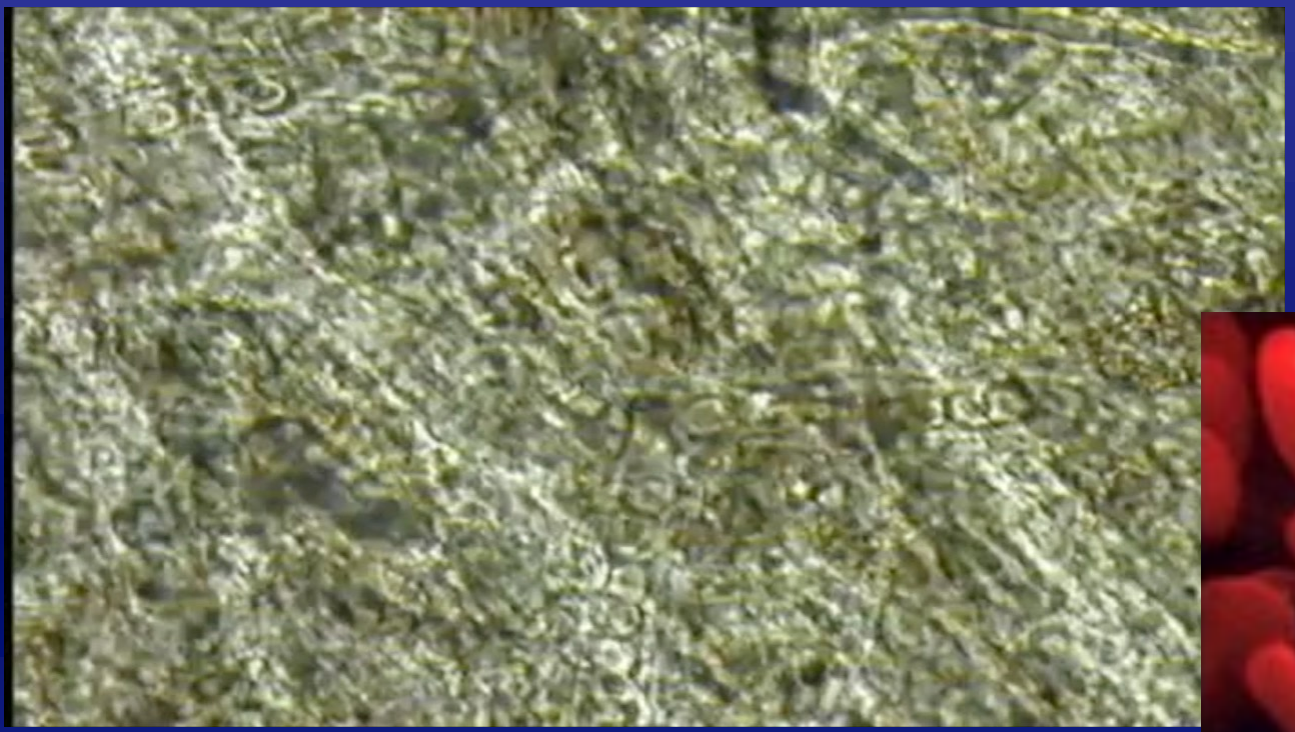
$$VO_{2max} = Q_{max} * a\text{-}vO_{2diffmax}$$

Limits of the Lung

LUNG → HEART → CIRCULATION → MUSCLE

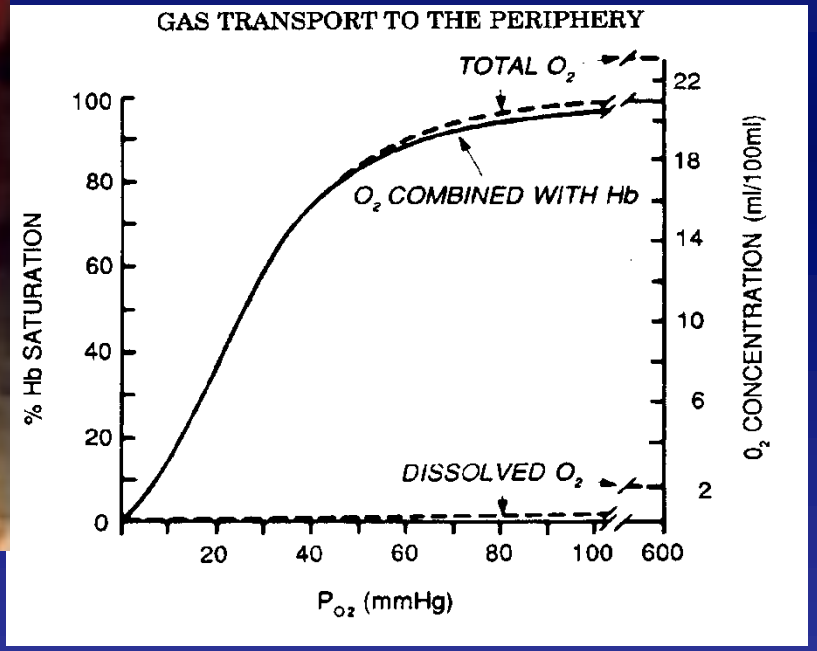


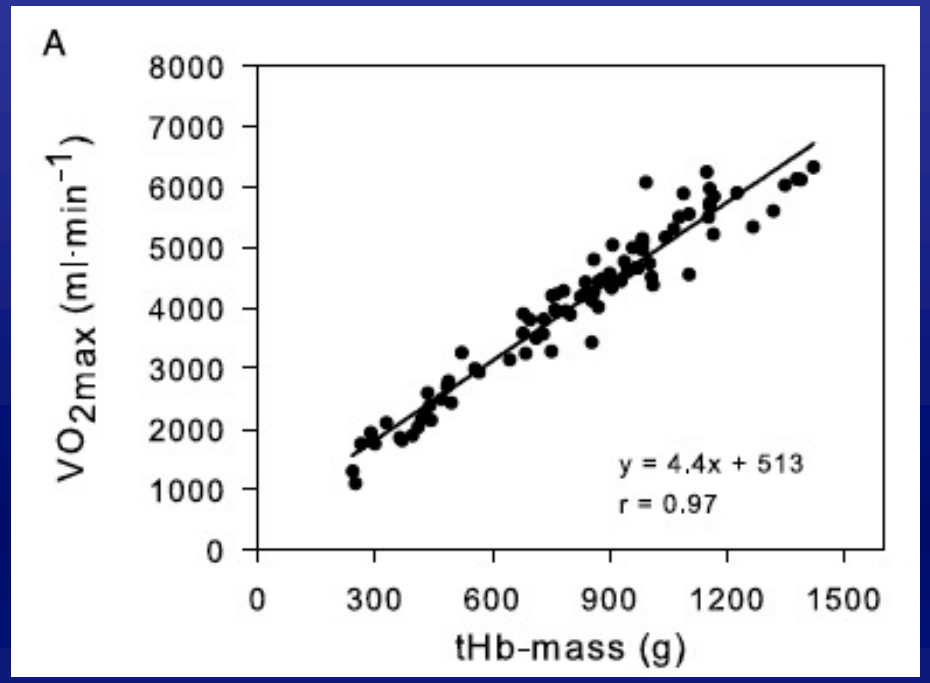
Limits of the Blood



- Hypervolemia

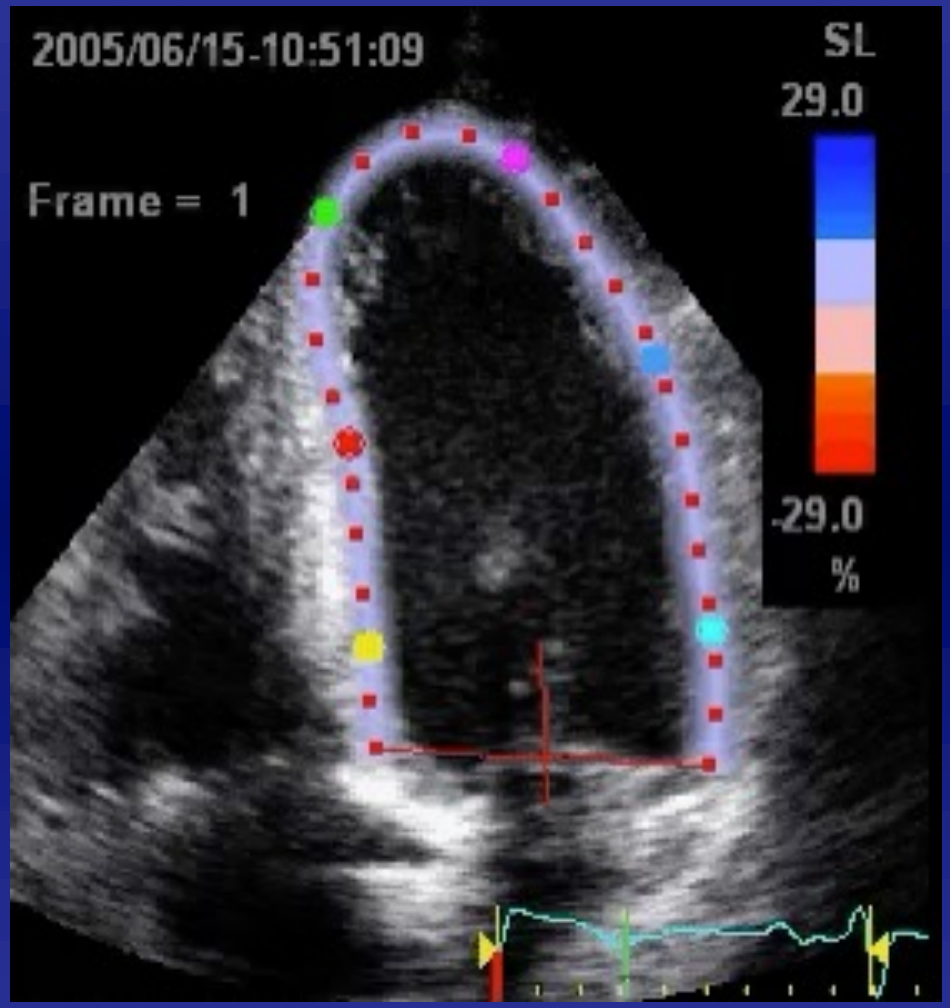
  (up to 20%): ⬆PV, RBC, Hb, Hct

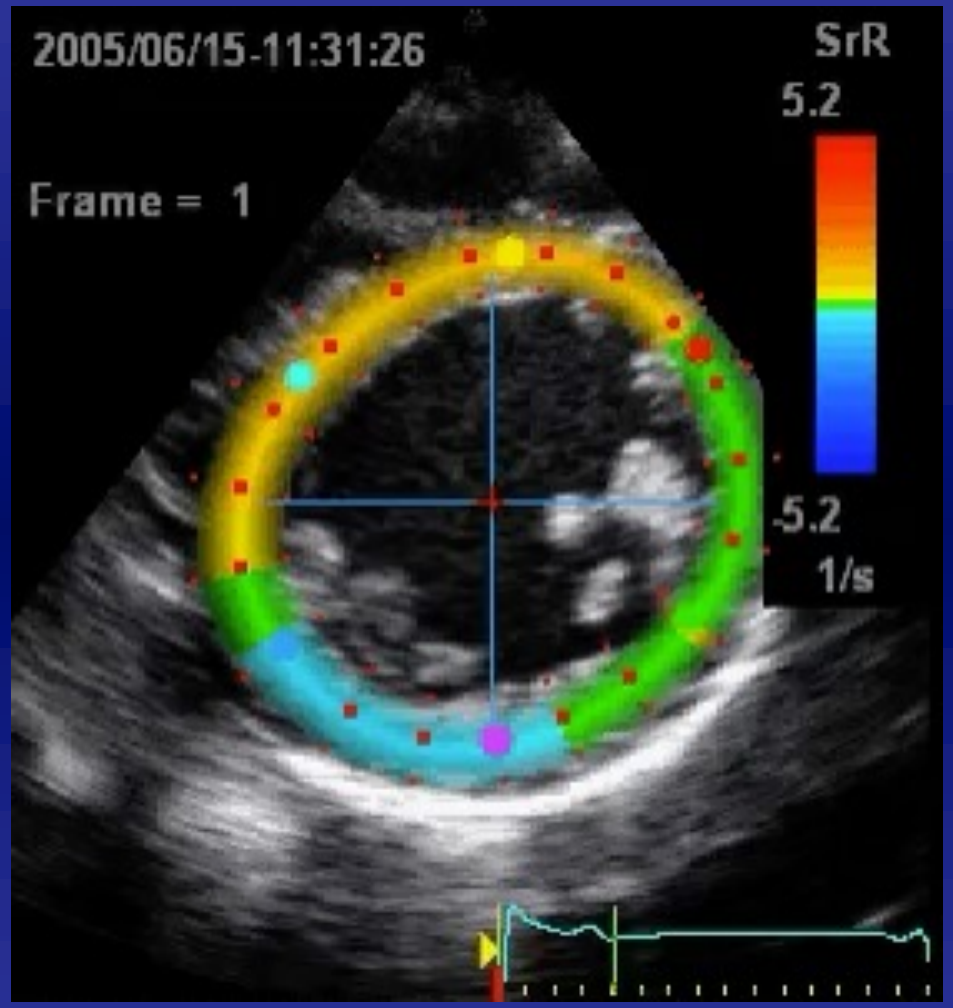




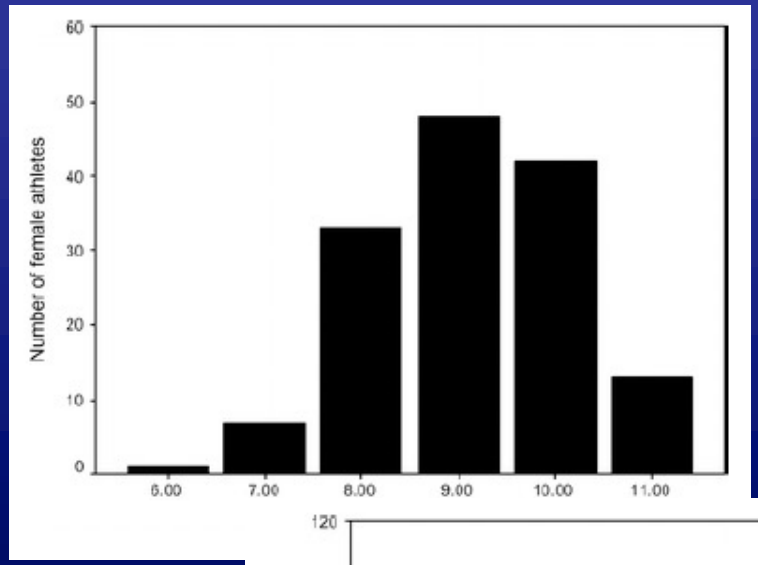
Schmidt & Prommer *Ex Sports Sci Rev 2010; 38:68-75.*

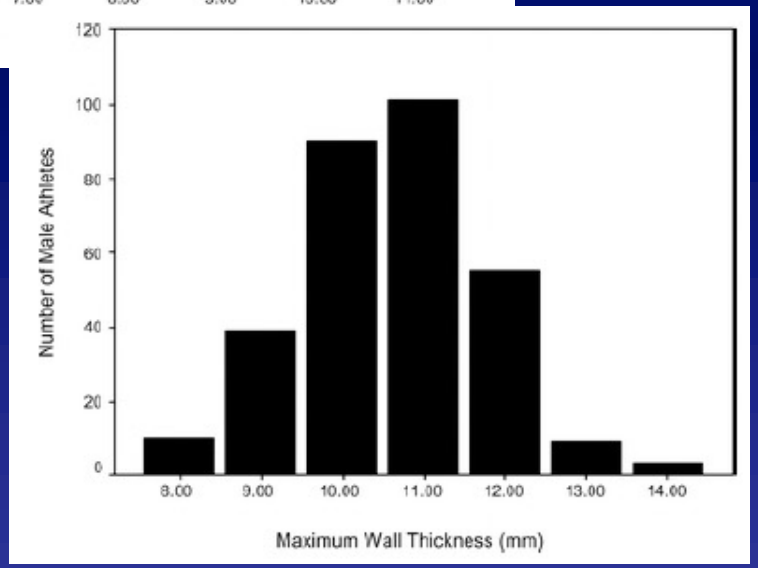
CARDIAC LIMITS



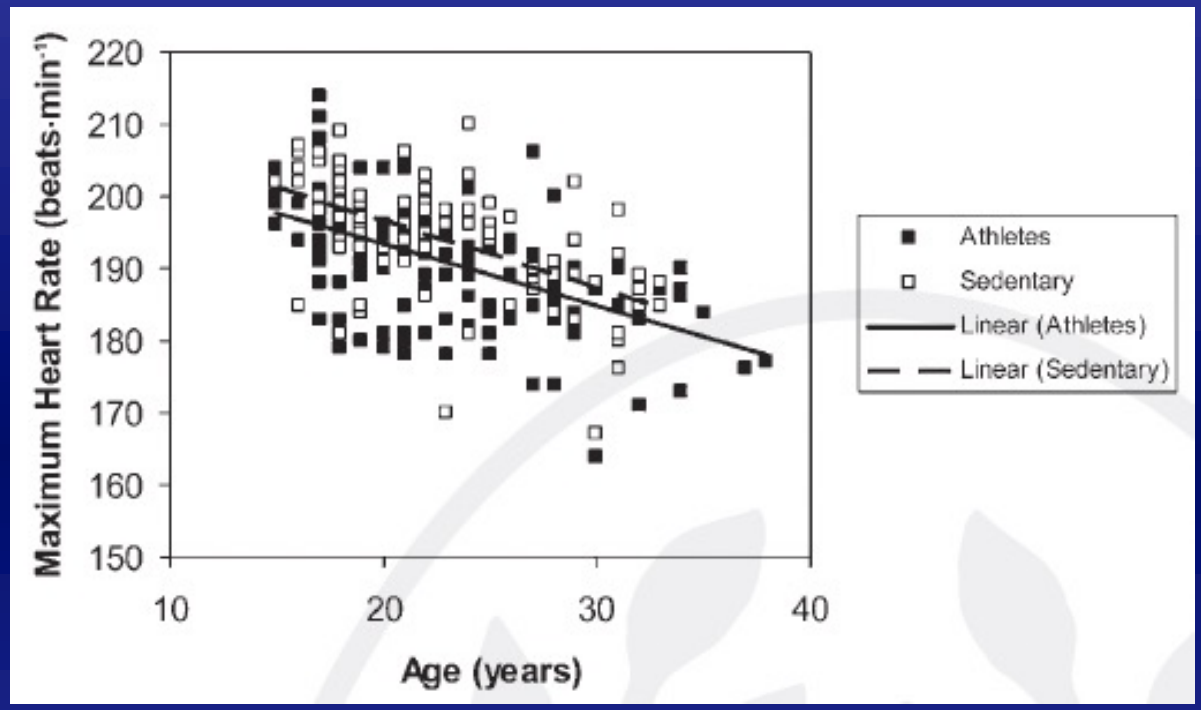


CARDIAC SIZE & HR_{max} LIMITS



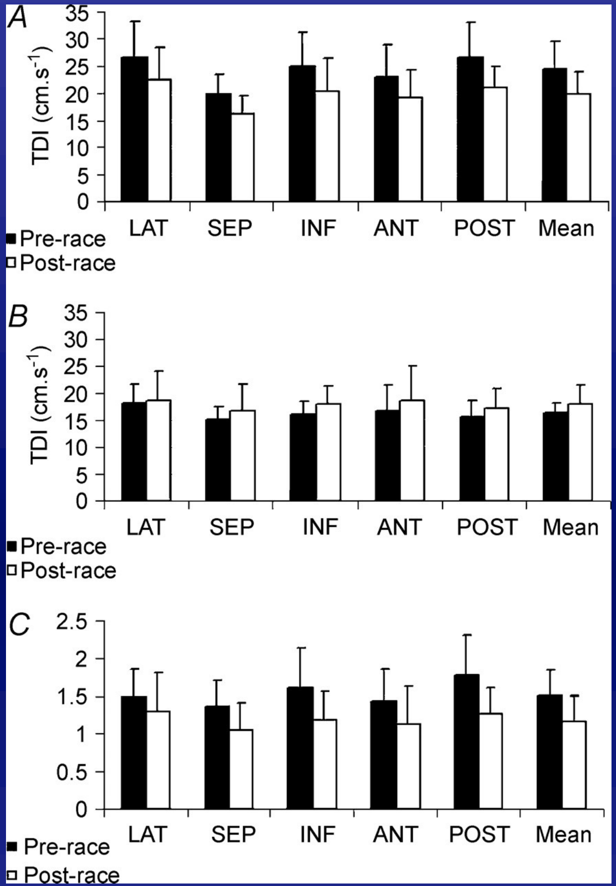


Whyte et al. 2004 *EJAP*

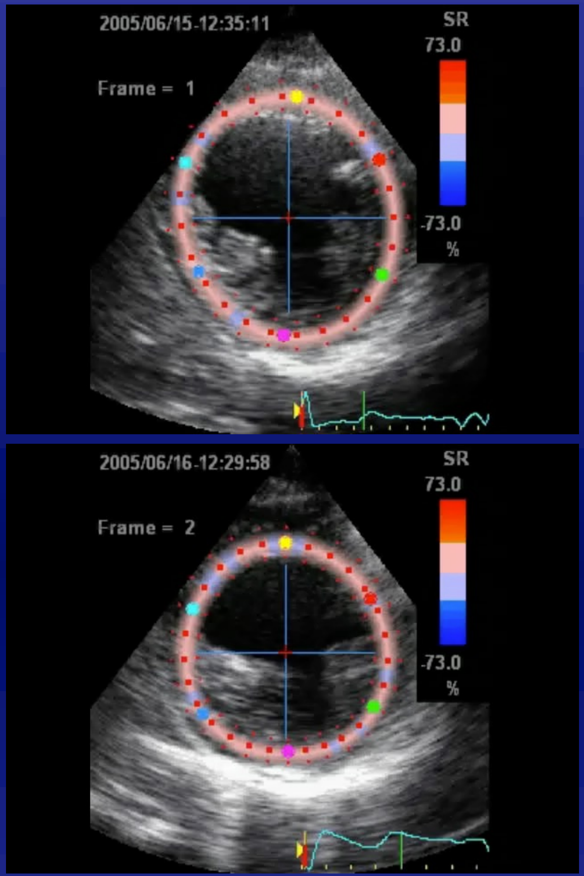


Whyte et al. *Int J Sports Med 2008; 29: 129–133*

CARDIAC FATIGUE & DAMAGE

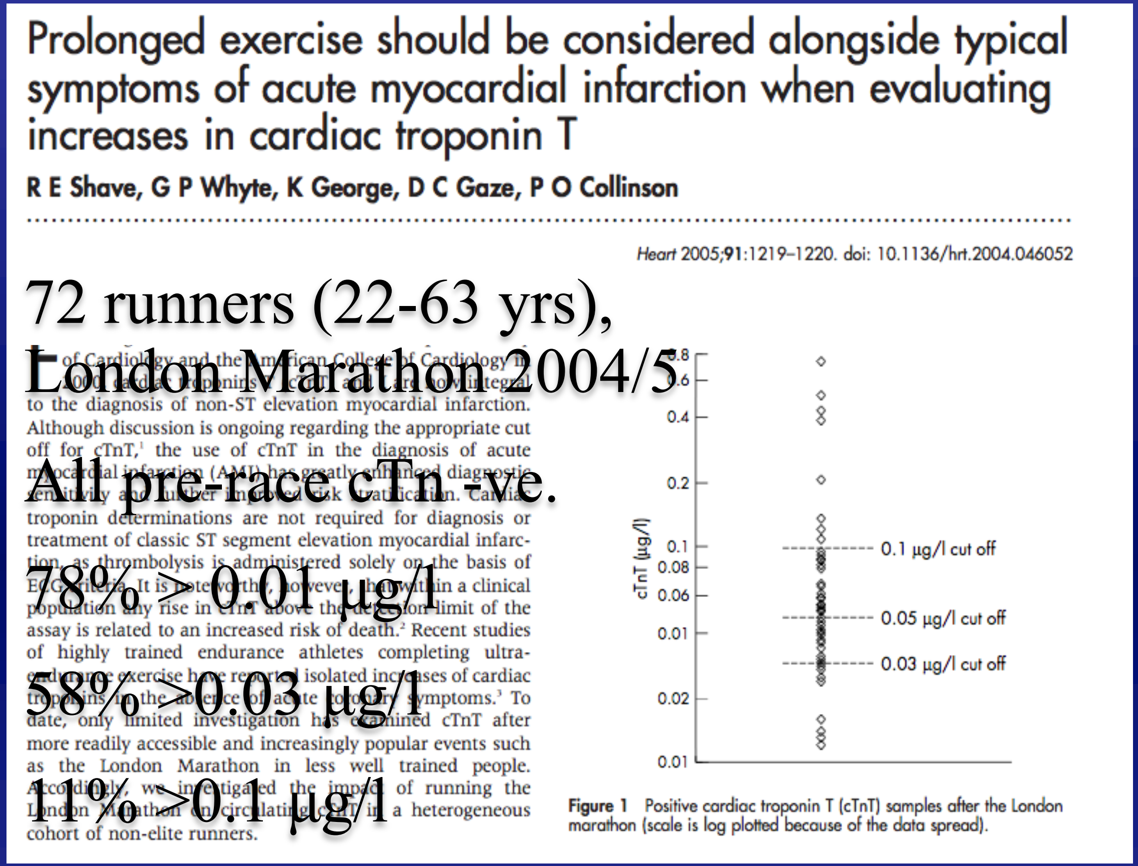


A-Early diastolic velocity (E'),
B-late diastolic velocity (A'),
C- E':A'



Significant regional and global changes in diastolic function

George, K. et al. 2005. *J Physiol*



Prolonged exercise should be considered alongside typical symptoms of acute myocardial infarction when evaluating increases in cardiac troponin T

R E Shave, G P Whyte, K George, D C Gaze, P O Collinson

Heart 2005;91:1219–1220. doi: 10.1136/hrt.2004.046052

Figure 1 Positive cardiac troponin T (cTnT) samples after the London marathon (scale is log plotted because of the data spread).

72 runners (22-63 yrs), London Marathon 2004/5

All pre-race cTn -ve.

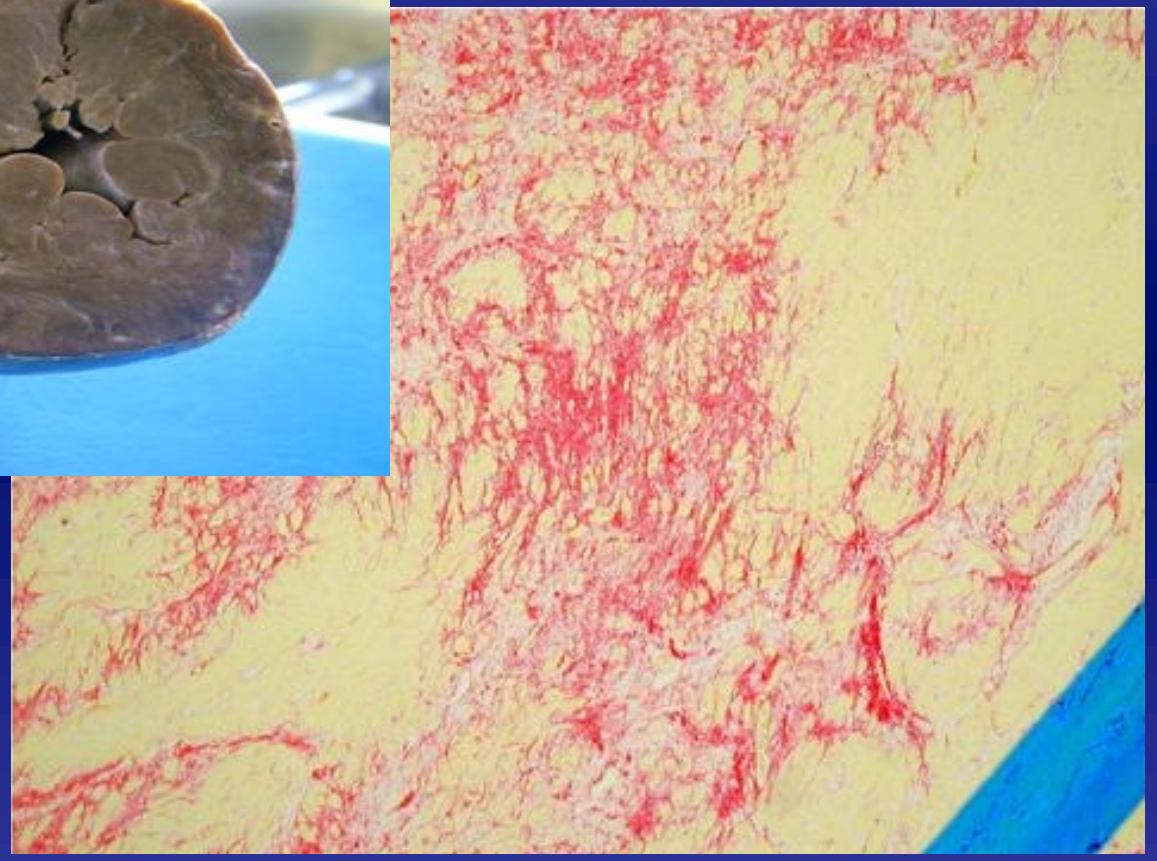
78% > 0.01 µg/l

58% >0.03 µg/l

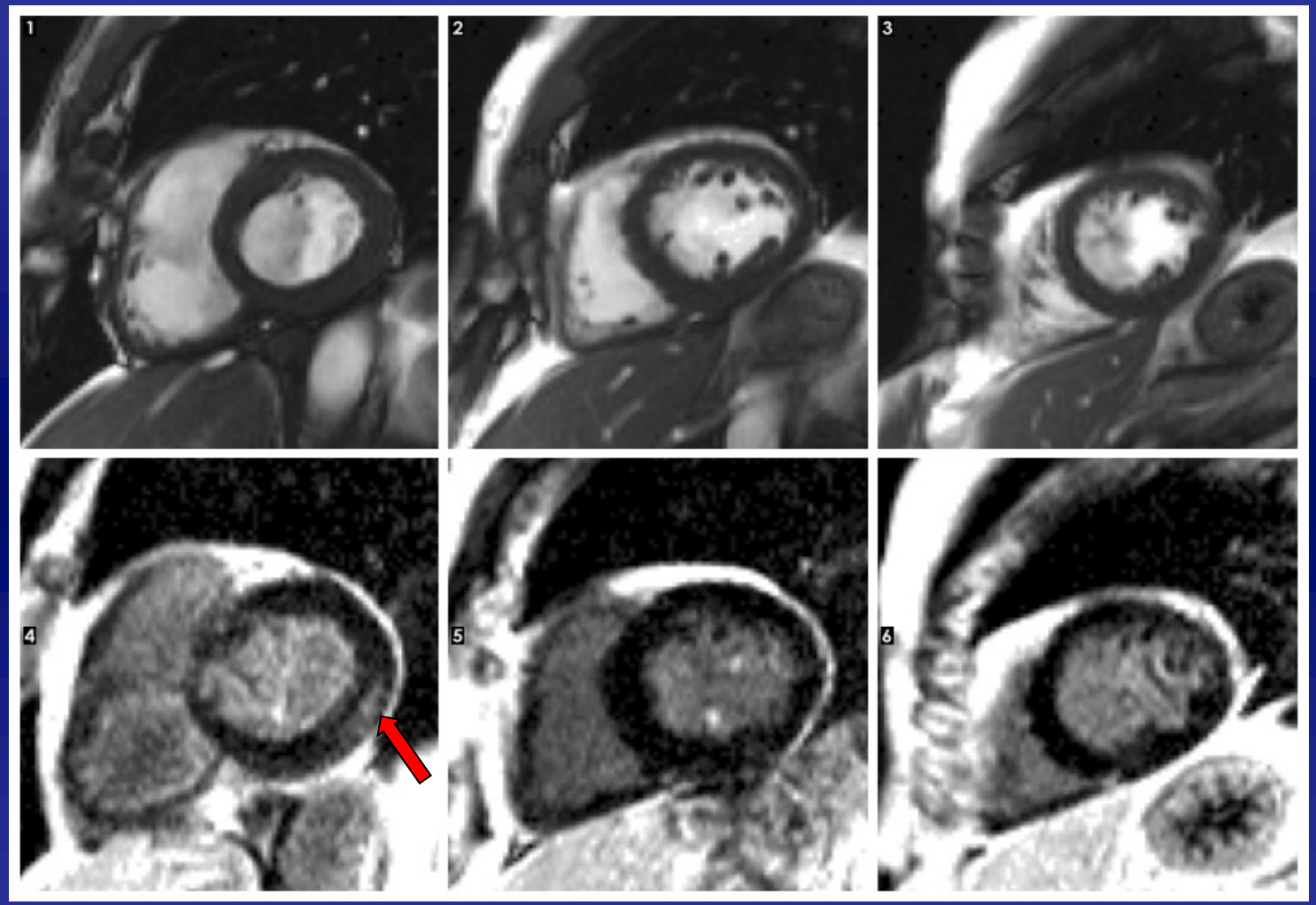
11% >0.1 µg/l

Shave et al. *Heart*, 2005

SCD in a Marathon Runner (RC)

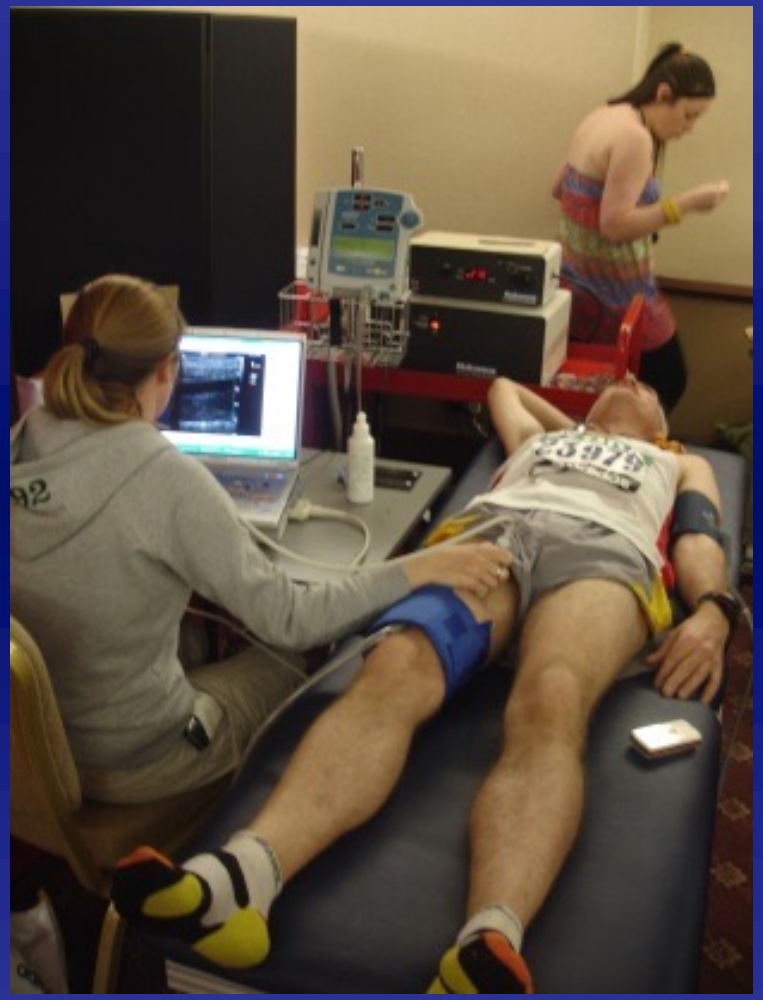


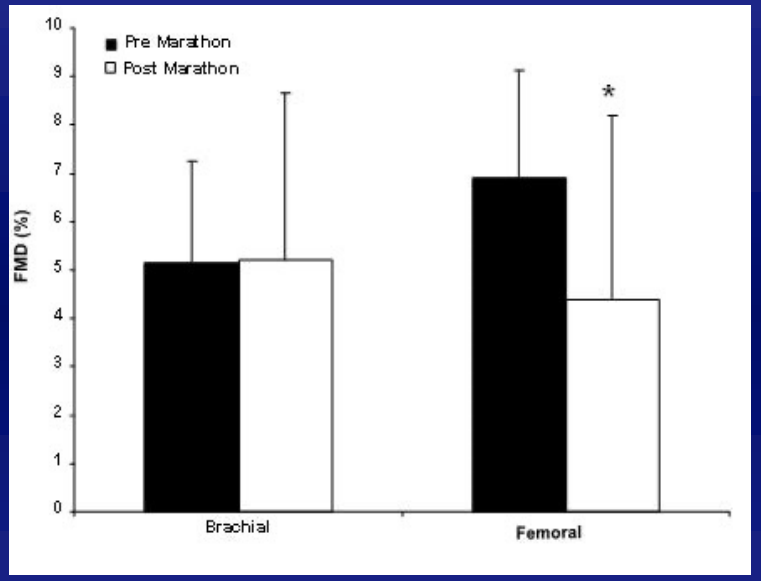
Myocardial Fibrosis in a Lifelong Endurance Runner (RH)



Wilson et al. BMJ Case Reports. 2009. doi:10.1136/bcr.12.2008.1345.

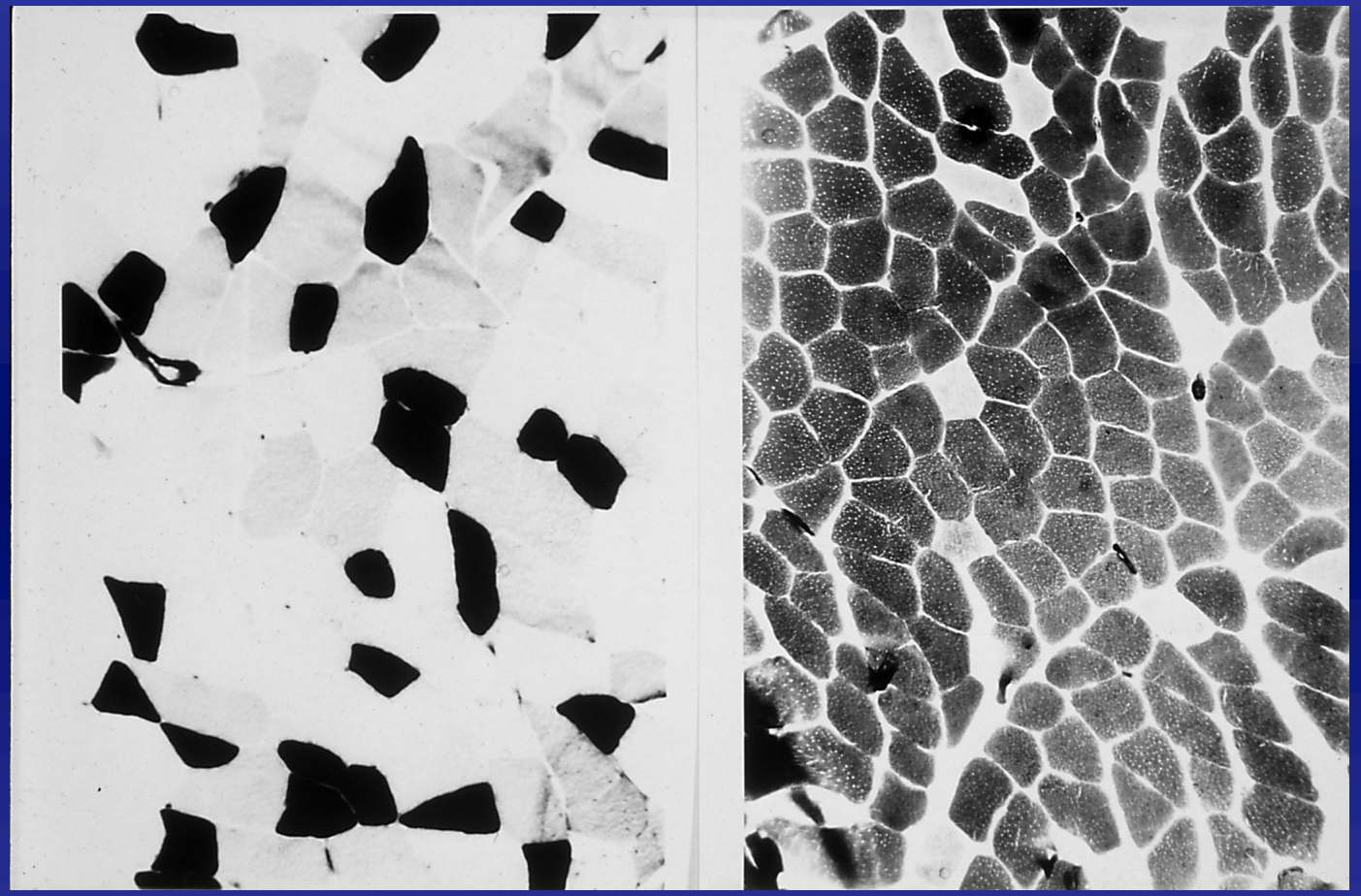
VASCULAR LIMITS





Dawson et al. 2008 *JAP*

Limits of the Muscles



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GENETIC LIMITS

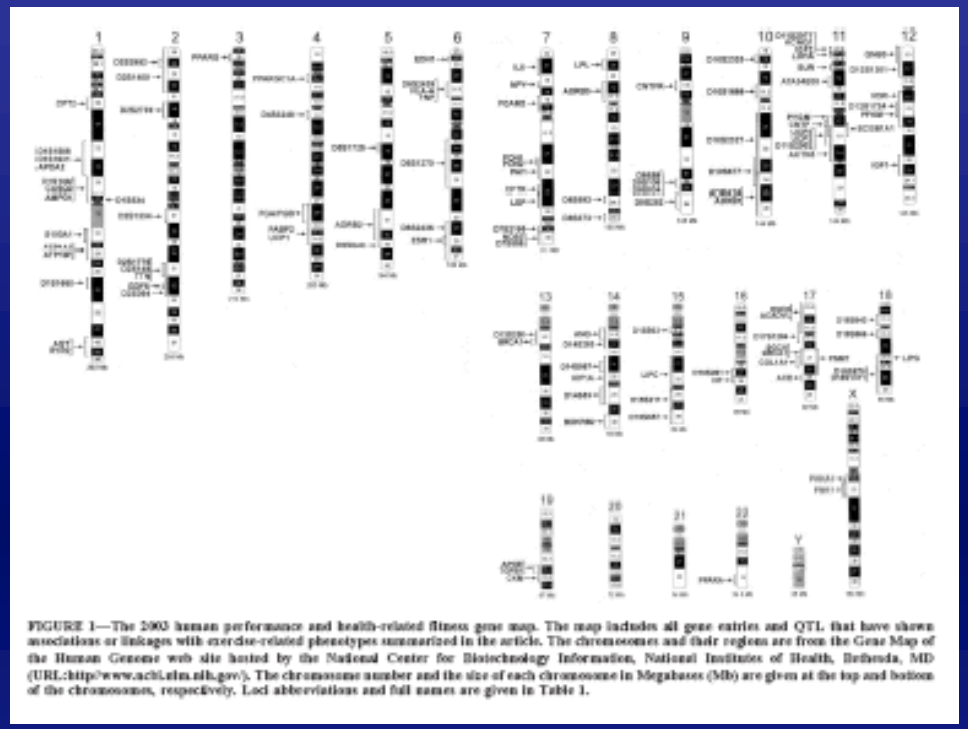


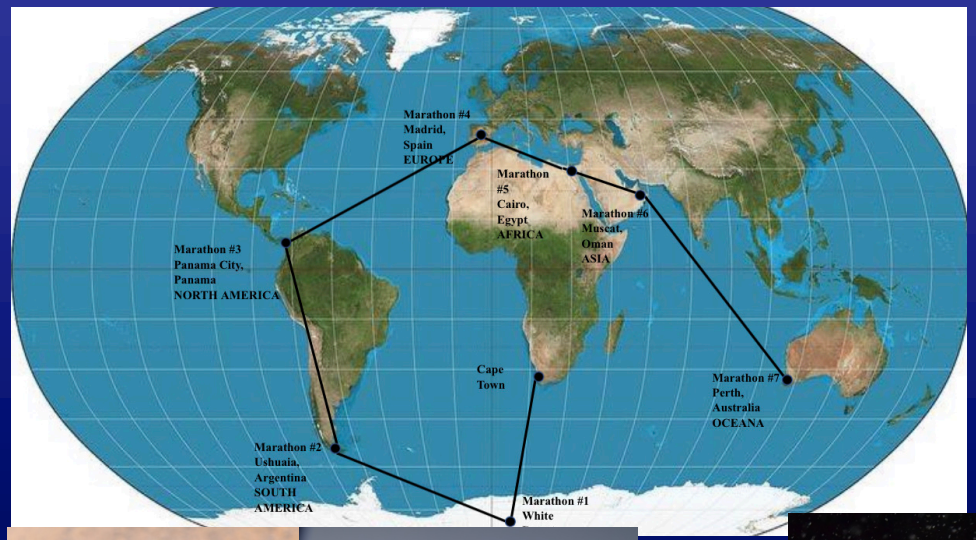
FIGURE 1—The 2003 human performance and health-related fitness gene map. The map includes all gene entries and QTL that have shown associations or linkages with exercise-related phenotypes summarized in the article. The chromosomes and their regions are from the Gene Map of the Human Genome web site hosted by the National Center for Biotechnology Information, National Institutes of Health, Bethesda, MD (URL:http\www.ncbi.nlm.nih.gov/). The chromosome number and the size of each chromosome in Megabases (Mb) are given at the top and bottom of the chromosomes, respectively. Loci abbreviations and full names are given in Table 1.

Association or linkage with Performance, fitness phenotype

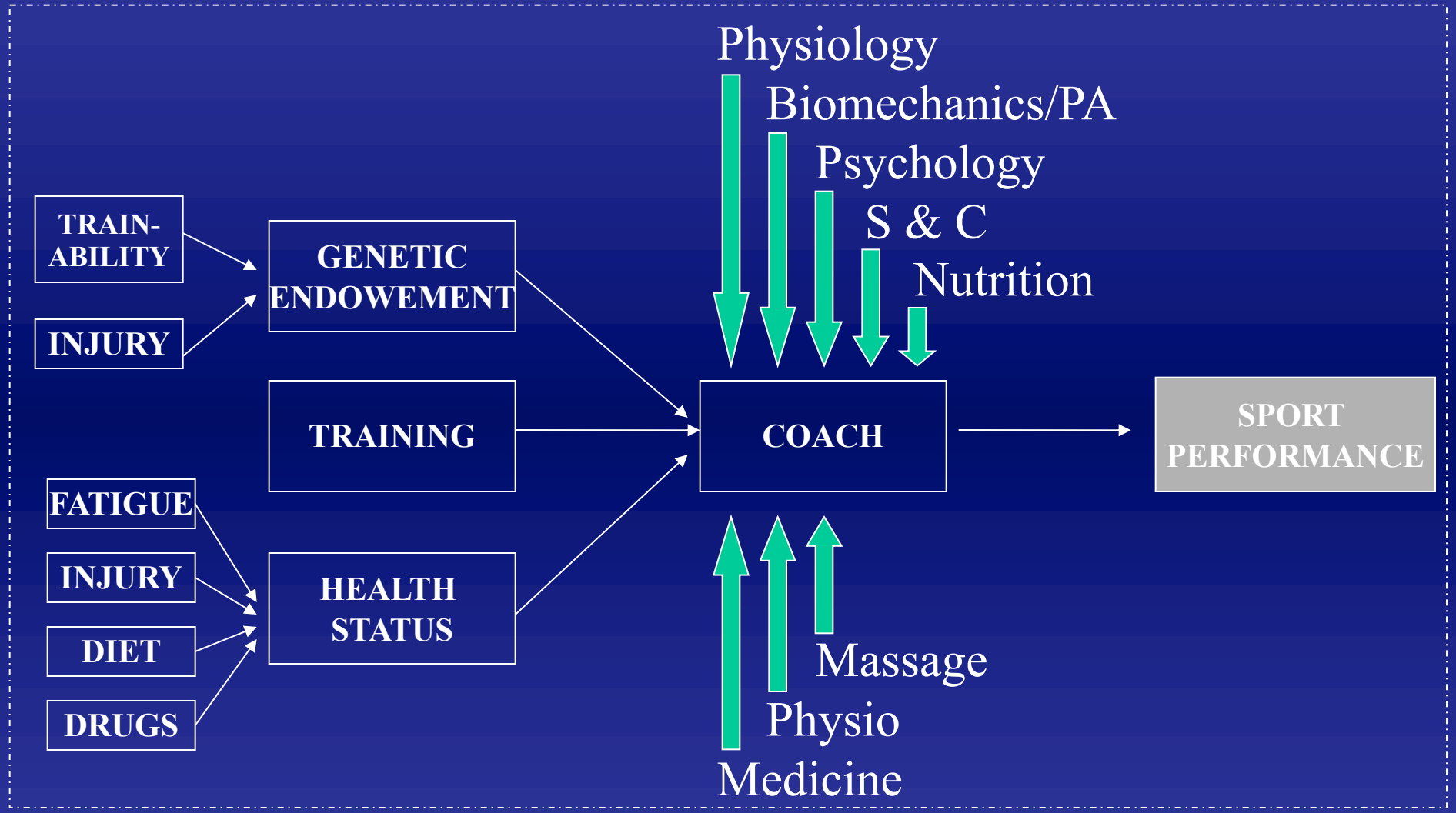
The Fitness and Performance gene map consists of 214 autosomal gene entries and quantitative trait loci plus 7 X chromosome and 18 mitochondrial genes

Bray et al., *MSSE* 2009;41(1):34-72

ENVIRONMENTAL LIMITS



Performance = Complex Bio-Psycho-Socio-Economic interaction

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