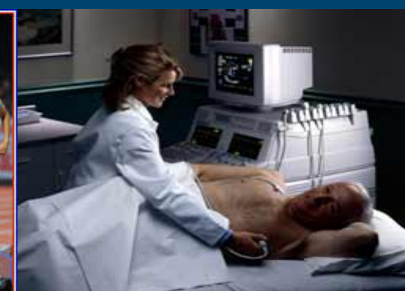
MASSACHUSETTS GENERAL HOSPITAL
HEART CENTER

Cardiovascular Performance Program

High Cardiac Output Athletes
The Role of Ventricular Remodeling



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Massachusetts General Hospital
Boston, MA

A Teaching Affiliate of Harvard Medical School

MASSACHUSETTS GENERAL HOSPITAL
HEART CENTER

Cardiovascular Performance Program

Conflicts: None

Athletic Affiliations:

Funding Sources:

- National Institutes of Health
- American Heart Association
- American Society of Echocardiography
- Department of Defense
- National Football League Player’s Association

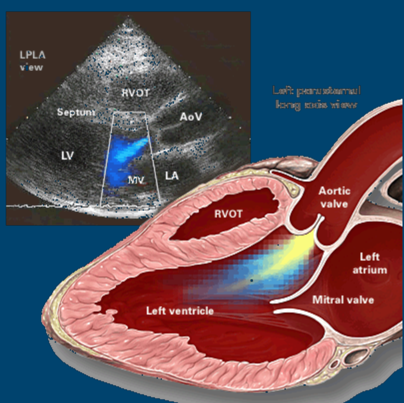
A Teaching Affiliate of Harvard Medical School

Cardiac Plasticity: *Remodeling*

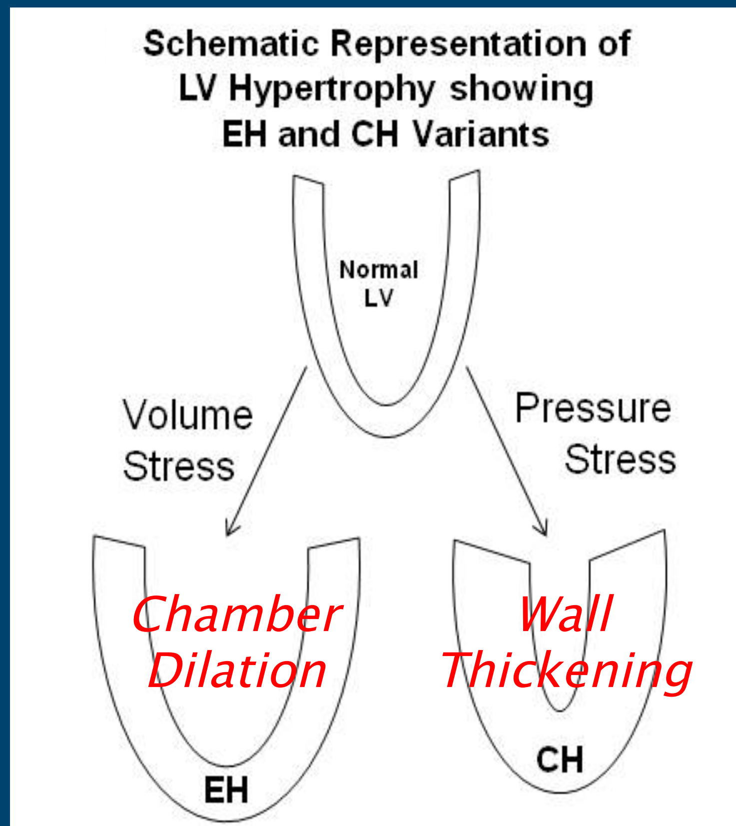
Cardiovascular Performance Program

Classic concept of LV remodeling……

Aortic Regurgitation



Volume Challenge



Aortic Stenosis

Pressure Challenge

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Cardiac Remodeling: *Physiology*

Cardiovascular Performance Program

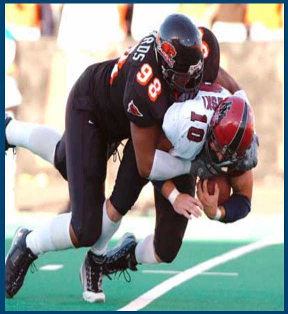
Endurance Activities


Sustained ↑ CO

- 4 to 5 times rest
- ↑ ↑ ↑ HR & ↑ SV
- Vasodilation

Volume Challenge

Strength Activities




Repetitive ↑ SBP

- Systolic BP > 300 mmHg
- Skeletal Mus. Contraction
- Vasoconstriction

Pressure Challenge

Cardiac Remodeling: *Physiology*

Cardiovascular Performance Program

Comparative Left Ventricular Dimensions in Trained Athletes

JOEL MORGANROTH, M.D., BARRY J. MARON, M.D., WALTER L. HENRY, M.D., and STEPHEN E. EPSTEIN, M.D., Bethesda, Maryland

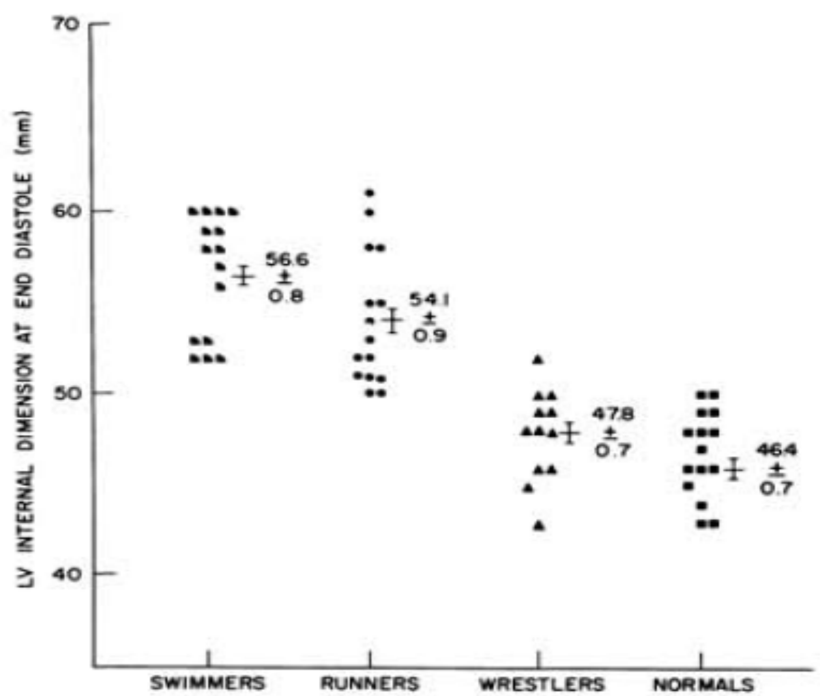


Figure 1. Echocardiographically measured left ventricular (LV) internal dimensions at end diastole in college athletes. Numbers represent mean values ± SEM. Data of swimmers and runners are statistically different from those of wrestlers and normal subjects ($P < 0.001$).

MISCELLANEOUS

Morphology of the "Athlete's Heart" Assessed by Echocardiography in 947 Elite Athletes Representing 27 Sports*

Paolo Spirito, MD, Antonio Pelliccia, MD, Michael A. Proschan, PhD, Maristella Granata, MD, Antonio Spataro, MD, Pietro Bellone, MD, Giovanni Caselli, MD, Alessandro Biffi, MD, Carlo Vecchio, MD, and Barry J. Maron, MD

In the present study, we used echocardiography in sports associated with large diastolic cavity

TABLE I Age, Gender, Body Surface Area, and Cardiac Dimensions in 947 Athletes Representing 27 Sports

Sport	Male (No.)	Female (No.)	Total (No.)	Overall Group (%)	Age (yr)	BSA	LVIDd (mm)	Wall Thickness (mm)
Rowing	92	3	95	10.0	21.1 ± 4.3	2.04 ± 0.1	56.0 ± 3.8	11.3 ± 1.3
Soccer	62	0	62	6.5	24.8 ± 4.3	1.95 ± 0.1	55.0 ± 4.3	10.0 ± 0.8
Rollerskating	32	26	58	6.1	19.7 ± 2.9	1.74 ± 0.2	49.0 ± 4.4	9.0 ± 1.0
Canoeing	51	8	59	6.2	20.1 ± 3.9	1.92 ± 0.1	54.5 ± 3.4	10.5 ± 1.6
Swimming	26	29	55	5.8	19.5 ± 3.2	1.82 ± 0.2	53.0 ± 4.8	9.4 ± 1.3
Volleyball	37	14	51	5.4	20.6 ± 4.3	2.09 ± 0.2	53.7 ± 3.7	9.4 ± 1.0
Endurance cycling	37	13	50	5.3	20.3 ± 3.5	1.84 ± 0.2	55.0 ± 5.3	10.5 ± 1.2
Pentathlon	36	14	50	5.3	19.5 ± 4.0	1.77 ± 0.1	52.4 ± 4.6	9.3 ± 1.0
Long-distance track	41	8	49	5.2	26.7 ± 4.5	1.77 ± 0.2	53.3 ± 3.6	10.3 ± 1.1
Tennis	31	15	46	4.9	17.0 ± 3.0	1.76 ± 0.1	50.1 ± 3.5	9.1 ± 1.0
Fencing	31	11	42	4.4	22.4 ± 3.4	1.86 ± 0.2	51.8 ± 5.3	9.3 ± 1.3
Sprint track	25	15	40	4.2	25.1 ± 2.8	1.80 ± 0.2	49.3 ± 4.1	9.1 ± 1.0
Alpine skiing	24	8	32	3.4	21.5 ± 2.5	1.89 ± 0.2	52.1 ± 3.6	9.0 ± 0.7
Cross-country skiing	24	7	31	3.3	24.5 ± 4.4	1.78 ± 0.1	54.6 ± 4.1	9.6 ± 0.9
Equestrian	23	5	28	3.0	28.1 ± 7.0	1.78 ± 0.1	50.5 ± 3.5	9.0 ± 0.8
Team handball	9	17	26	2.7	22.5 ± 2.9	1.87 ± 0.2	51.9 ± 4.5	8.5 ± 0.9
Yachting	20	4	24	2.5	27.1 ± 4.8	1.89 ± 0.2	51.3 ± 4.1	9.1 ± 0.9
Roller hockey	23	0	23	2.4	22.7 ± 3.0	1.92 ± 0.1	53.5 ± 3.8	9.7 ± 0.9
Water polo	21	0	21	2.2	24.5 ± 2.9	2.03 ± 0.1	54.7 ± 3.4	10.7 ± 0.6
Taekwondo	14	3	17	1.8	21.6 ± 3.0	1.76 ± 0.2	50.6 ± 4.0	8.7 ± 1.3
Wrestling/judo	14	2	16	1.7	24.6 ± 3.4	1.94 ± 0.3	52.6 ± 5.6	10.3 ± 0.9
Bobsledding	16	0	16	1.7	26.3 ± 3.5	2.09 ± 0.1	55.1 ± 2.1	9.7 ± 0.5
Sprint cycling	13	2	15	1.6	20.3 ± 1.9	1.92 ± 0.2	54.3 ± 4.5	10.1 ± 0.9
Boxing	14	0	14	1.5	22.6 ± 4.3	1.86 ± 0.3	52.5 ± 4.0	9.8 ± 1.1
Diving	7	4	11	1.2	23.5 ± 3.2	1.71 ± 0.2	49.6 ± 3.3	8.7 ± 1.2
Field weight events	8	1	9	1.0	24.4 ± 3.6	2.27 ± 0.2	55.6 ± 4.3	10.0 ± 0.6
Weightlifting	7	0	7	0.7	24.6 ± 2.1	1.97 ± 0.2	53.3 ± 4.0	10.5 ± 0.7

BSA = body surface area; LVIDd = left ventricular internal diastolic dimension.

Research (CNR), Project No. 8-4-3.

judged to be free of systemic or cardiovascular disease,

Historical Data: *Limitations*

Cardiovascular Performance Program

Observation: *Basketball Players are Tall*

Historical Data: *Limitations*

Cardiovascular Performance Program

Observation: *Basketball Players are Tall*

Explanation ?

Tall people self-select for basketball

Basketball makes people grow tall

Historical Data: *Causality?*

Cardiovascular Performance Program

Does exercise cause heart enlargement or do people born with "big hearts" simply self select for sport?

MASSACHUSETTS GENERAL HOSPITAL
HEART CENTER

The Harvard Athlete Initiative (HAI)

Cardiovascular Performance Program

A platform for longitudinal, repeated measures studies of CV adaptation to exercise.

THE HARVARD ATHLETE INITIATIVE 2005-2018

Jeremy Lin – NBA

Ryan Fitzpatrick – NFL

Esther Lofgren – USA

Andrew Campbell – USA

HAI: *Sport Specificity of EICR*

Cardiovascular Performance Program

Strength Athletes

Endurance Athletes

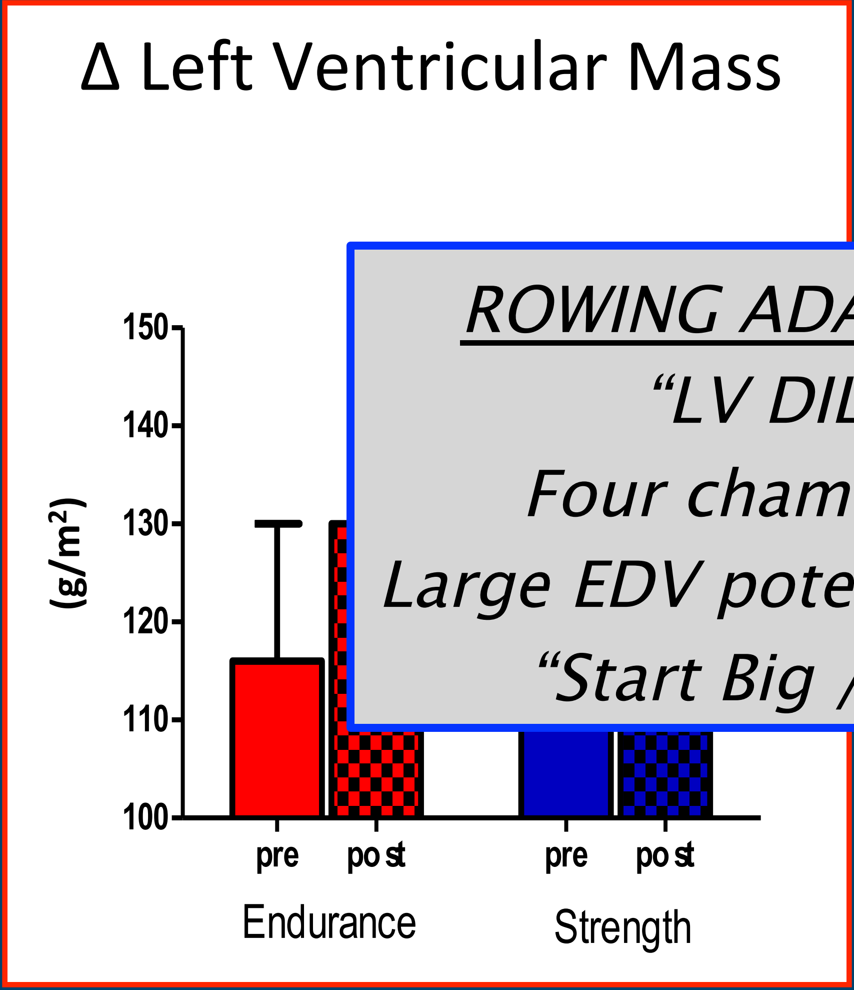
Do these hearts change and if so do they do so differently?

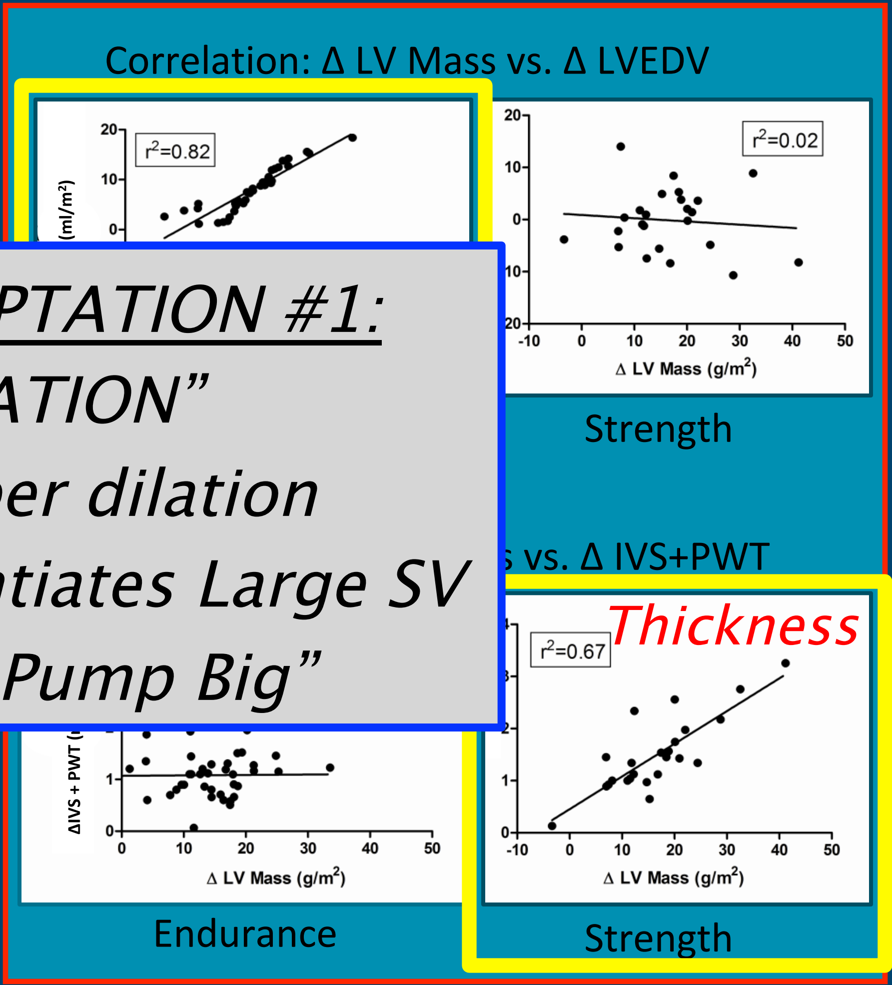
Pre-Study Period (48 days)

Study Period (90 days)

June July August September October November

HAI: *Sport Specific of EICR*





<u>ROWING ADAPTATION #1:</u>

"LV DILATION"

Four chamber dilation

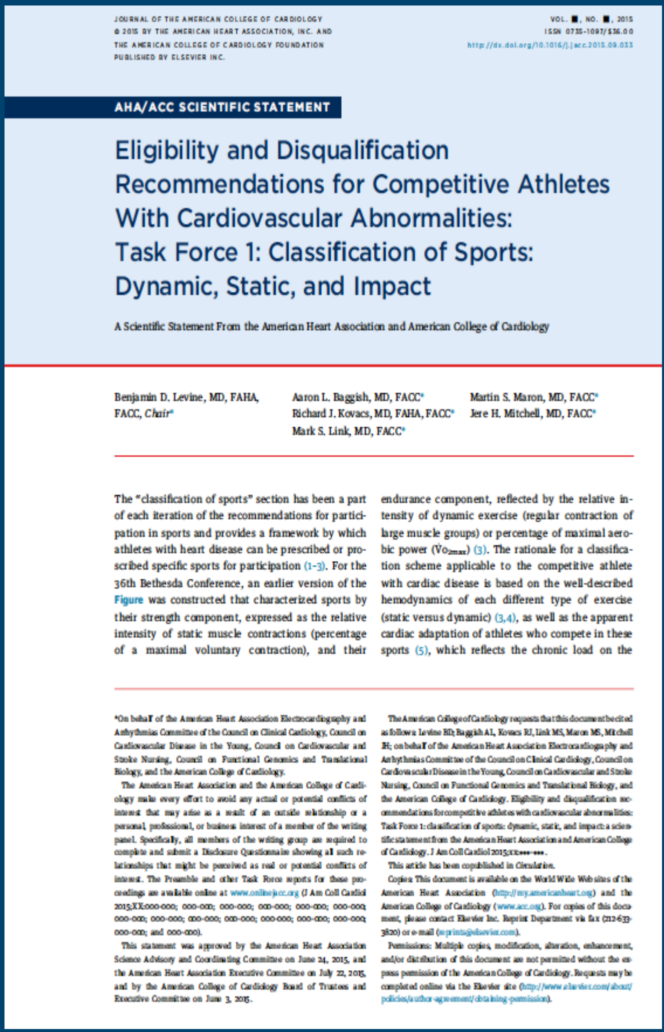
Large EDV potentiates Large SV

"Start Big / Pump Big"

J Appl Physiol 2008;104:1121

Cardiac Remodeling: *Physiology*

Cardiovascular Performance Program



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AHA/ACC SCIENTIFIC STATEMENT

Eligibility and Disqualification Recommendations for Competitive Athletes With Cardiovascular Abnormalities: Task Force 1: Classification of Sports: Dynamic, Static, and Impact

A Scientific Statement From the American Heart Association and American College of Cardiology

Benjamin D. Levine, MD, FAHA, FACC, *Chair**
Aaron L. Baggish, MD, FACC*
Richard J. Kovacs, MD, FAHA, FACC*
Mark S. Link, MD, FACC*
Martin S. Maron, MD, FACC*
Jere H. Mitchell, MD, FACC*

The "classification of sports" section has been a part of each iteration of the recommendations for participation in sports and provides a framework by which athletes with heart disease can be prescribed or proscribed specific sports for participation (1-3). For the 36th Bethesda Conference, an earlier version of the Figure was constructed that characterized sports by their strength component, expressed as the relative intensity of static muscle contractions (percentage of a maximal voluntary contraction), and their endurance component, reflected by the relative intensity of dynamic exercise (regular contraction of large muscle groups) or percentage of maximal aerobic power ($\dot{V}o_{2max}$) (3). The rationale for a classification scheme applicable to the competitive athlete with cardiac disease is based on the well-described hemodynamics of each different type of exercise (static versus dynamic) (3,4), as well as the apparent cardiac adaptation of athletes who compete in these sports (5), which reflects the chronic load on the

*On behalf of the American Heart Association Electrocardiography and Arrhythmias Committee of the Council on Clinical Cardiology, Council on Cardiovascular Disease in the Young, Council on Cardiovascular and Stroke Nursing, Council on Functional Genomics and Translational Biology, and the American College of Cardiology.

The American Heart Association and the American College of Cardiology make every effort to avoid any actual or potential conflicts of interest that may arise as a result of an outside relationship or a personal, professional, or business interest of a member of the writing panel. Specifically, all members of the writing group are required to complete and submit a Disclosure Questionnaire showing all such relationships that might be perceived as real or potential conflicts of interest. The Preamble and other Task Force reports for these proceedings are available online at www.onlinejacc.org (J Am Coll Cardiol 2015;XX:000-000; 000-000; 000-000; 000-000; 000-000; 000-000; 000-000; 000-000; 000-000; 000-000; 000-000; 000-000; 000-000; 000-000; and 000-000).

This statement was approved by the American Heart Association Science Advisory and Coordinating Committee on June 24, 2015, and the American Heart Association Executive Committee on July 22, 2015, and by the American College of Cardiology Board of Trustees and Executive Committee on June 3, 2015.

The American College of Cardiology requests that this document be cited as follows: Levine BD, Baggish AL, Kovacs RJ, Link MS, Maron MS, Mitchell JH; on behalf of the American Heart Association Electrocardiography and Arrhythmias Committee of the Council on Clinical Cardiology, Council on Cardiovascular Disease in the Young, Council on Cardiovascular and Stroke Nursing, Council on Functional Genomics and Translational Biology, and the American College of Cardiology. Eligibility and disqualification recommendations for competitive athletes with cardiovascular abnormalities: Task Force 1: classification of sports: dynamic, static, and impact: a scientific statement from the American Heart Association and American College of Cardiology. J Am Coll Cardiol 2015;XX:•••-•••.

This article has been copublished in *Circulation*.

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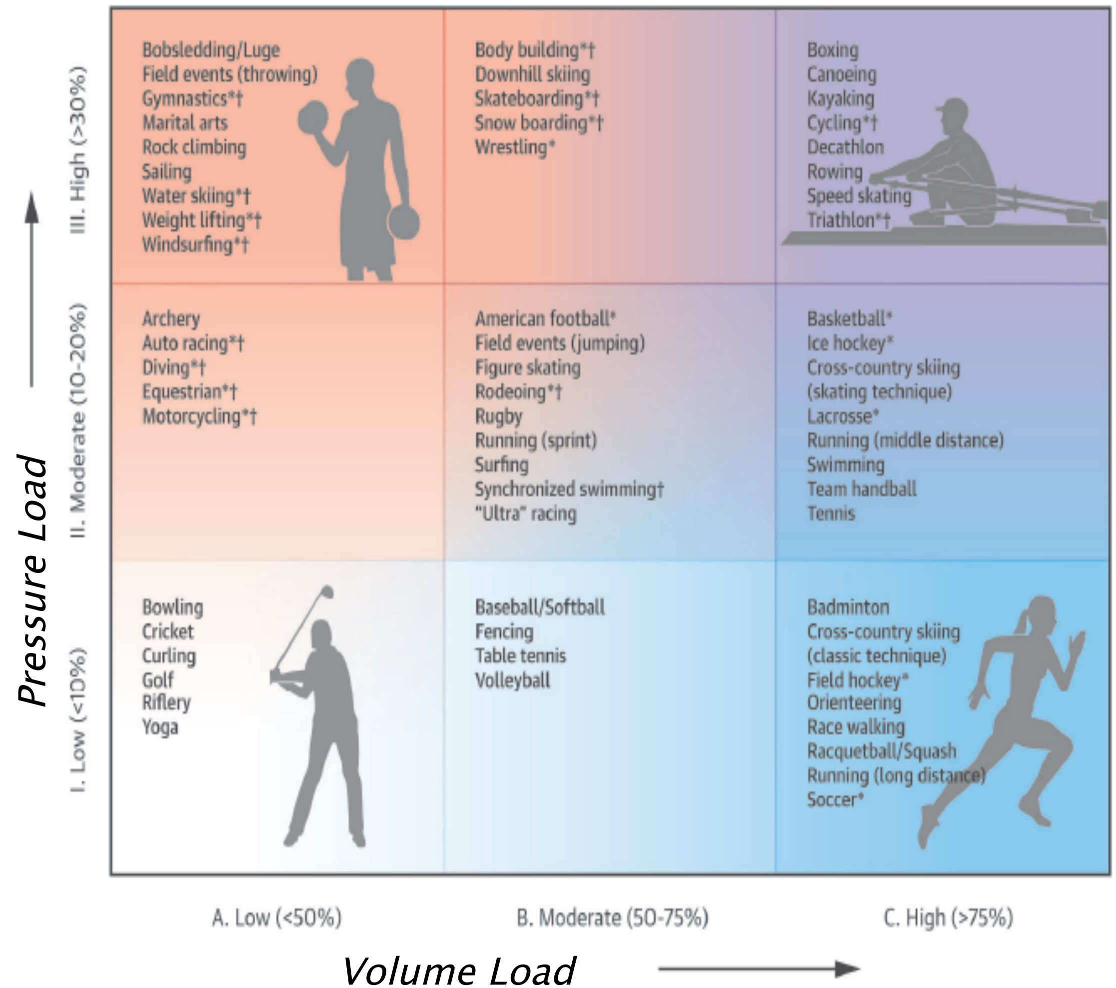


Levine, Baggish, et al. JACC 2015

Endurance Sport Physiology

MGH 1811 Cardiovascular Performance Program

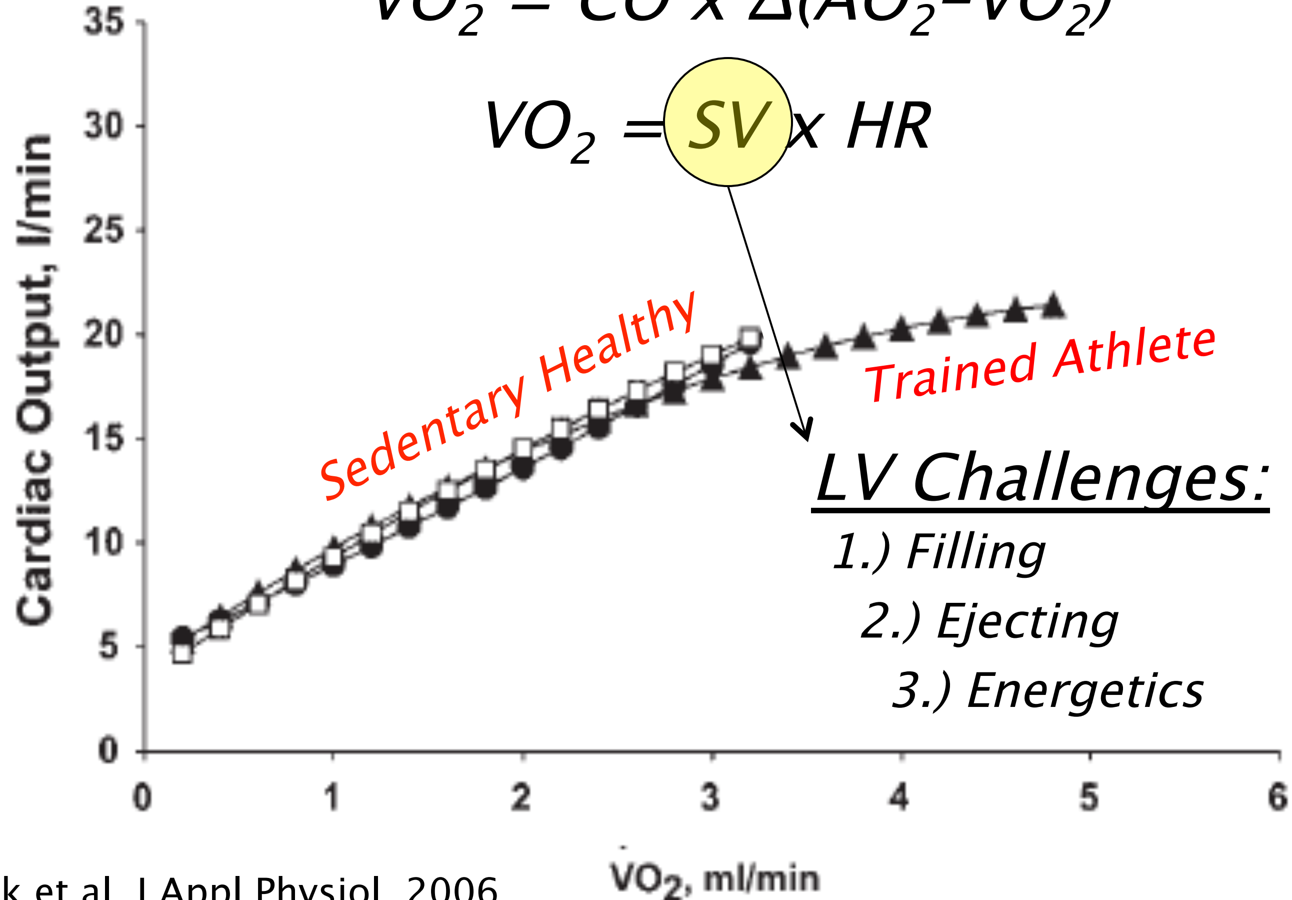
The Role of the Heart in Sport Performance

Increasing Pressure Load

High CO

$$VO_2 = CO \times \sout{\Delta(AO_2 - VO_2)}$$

$$VO_2 = SV \times HR$$



LV Challenges:

1.) Filling
2.) Ejecting
3.) Energetics

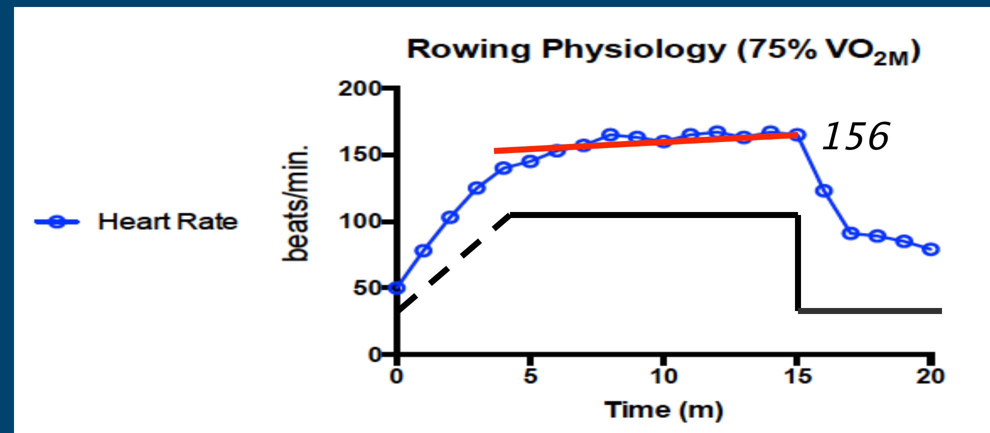
Beck et al. J Appl Physiol. 2006

Endurance Sport Physiology

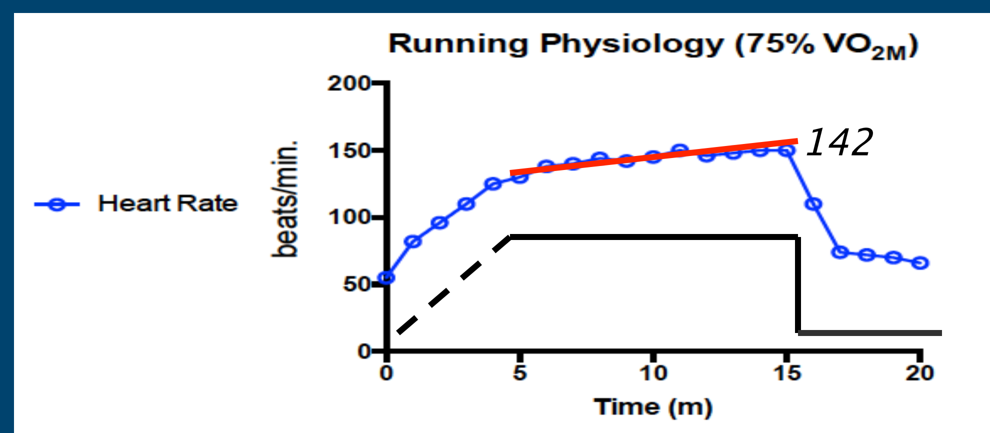
Cardiovascular Performance Program

Increasing Pressure Load

High CO

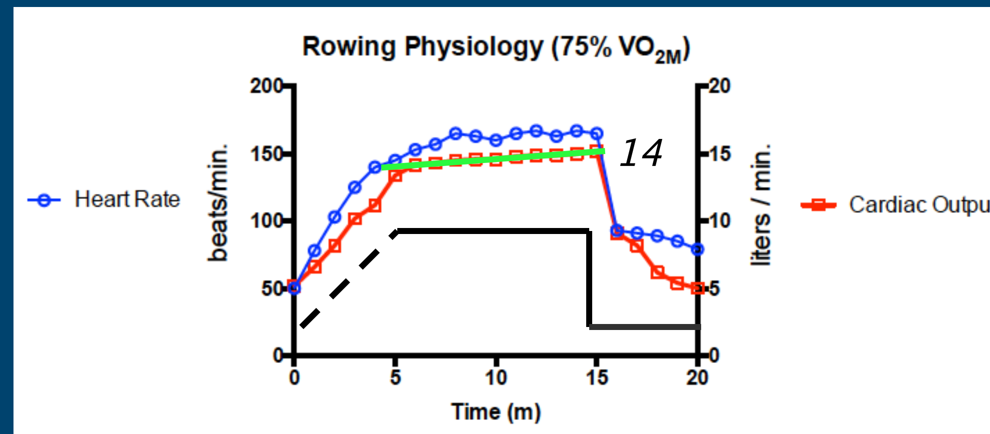


Heart Rate ~ Work "Tightly Coupled"....All Endurance Sports

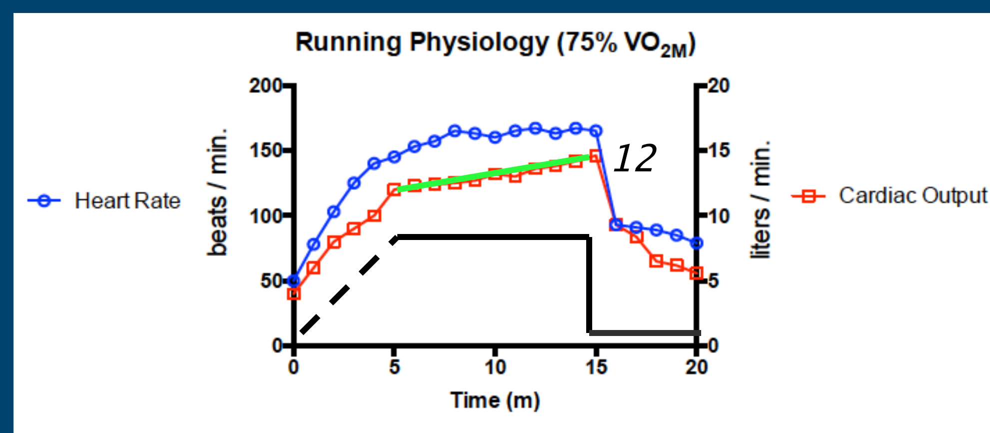


Endurance Sport Physiology

Cardiovascular
Performance
Program



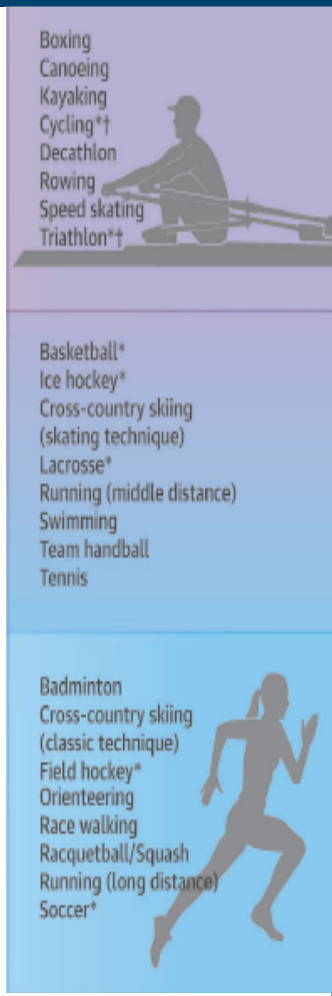
CO (HR x SV)~ Work "Tightly Coupled"....All Endurance Sports



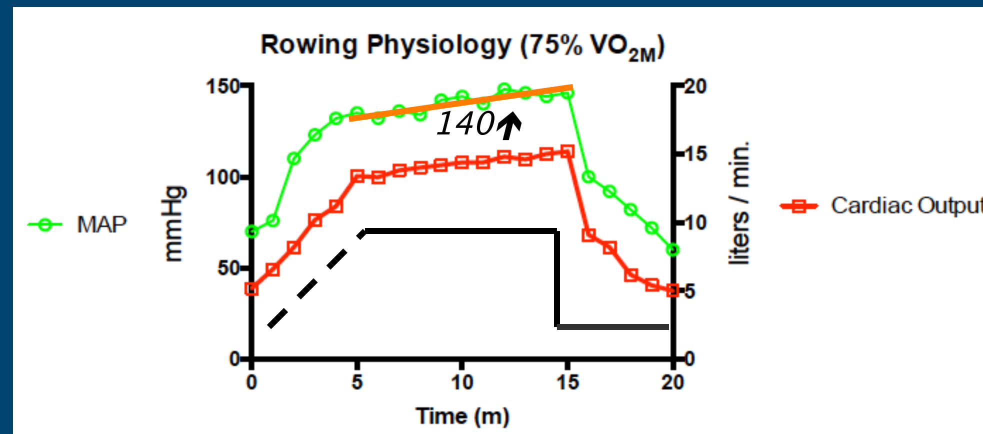
Endurance Sport Physiology

Cardiovascular Performance Program

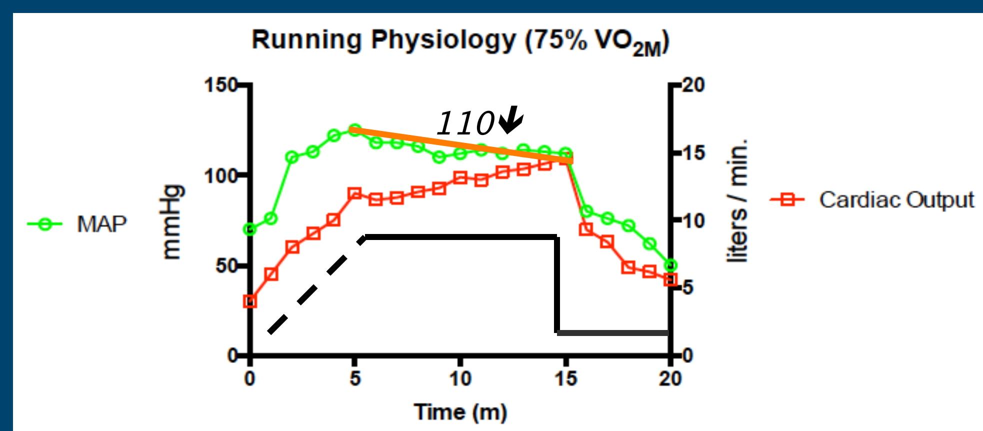
Increasing Pressure Load



High CO

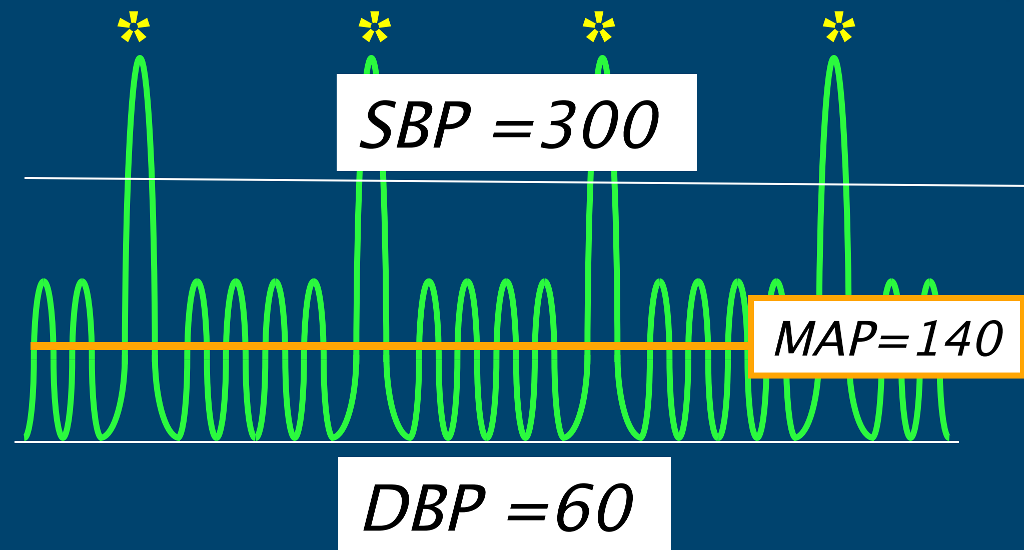


Arterial Blood Pressure Is Endurance Sport Specific

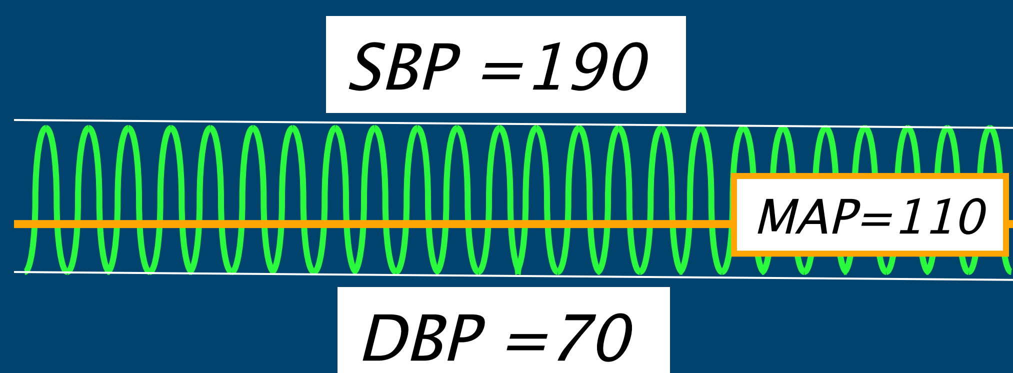


Endurance Sport Physiology

10 Sec. BP Tracings

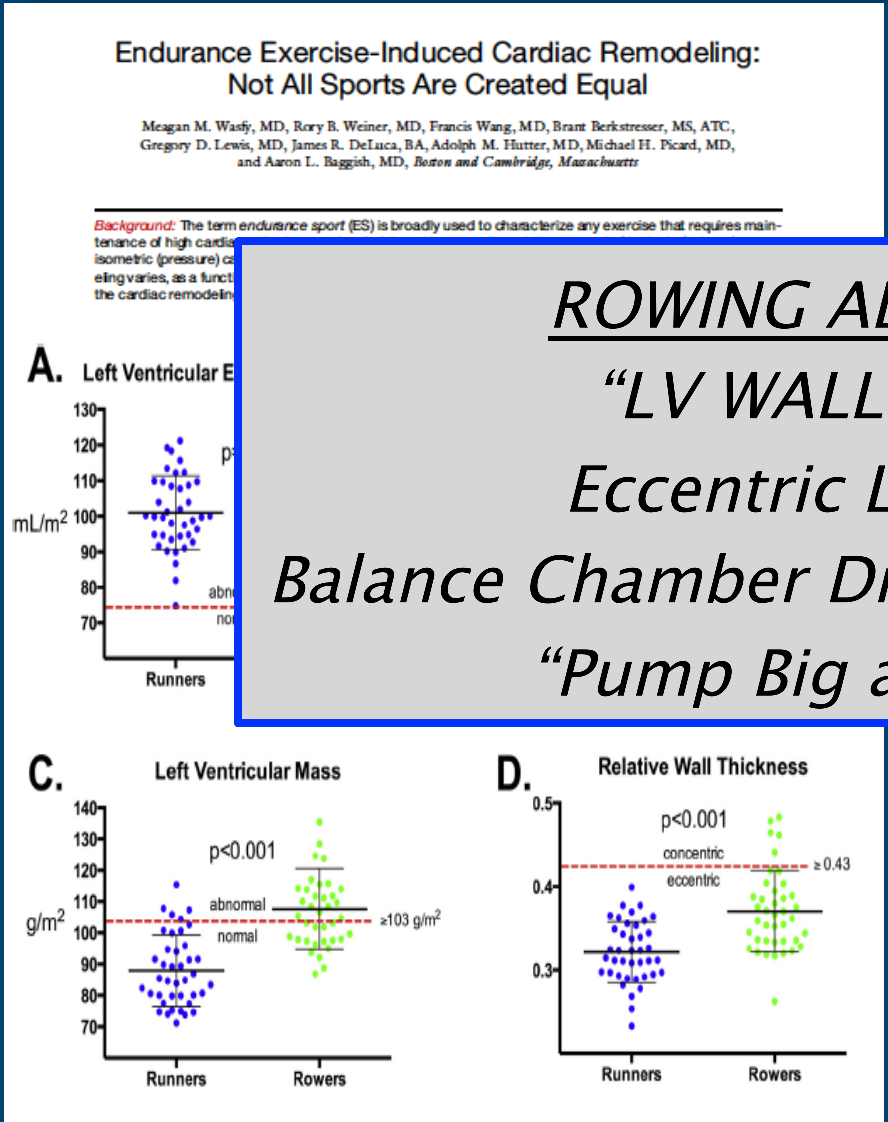


Rowing requires high CO in the face of pressure



Endurance Remodeling Variants

Cardiovascular Performance Program



ROWING ADAPTATION #2:

"LV WALL THICKENING"

Eccentric LV Hypertrophy

Balance Chamber Dilation & Wall Thickening

"Pump Big at Minimal Cost"

Wasfy et al. JASE 2015

Endurance: LV Filling

Having a Big Heart at Rest ≠ *Big Heart During Exercise*

FUNDAMENTAL CHALLENGE
FOR THE ENDURANDCE HEART…

Filling NOT Pumping

No Matter How Big You Are,
If you can't fill, you can't pump

Heart Rate 60

SEP = 300 ms / DFP = 700 ms

Heart Rate 160

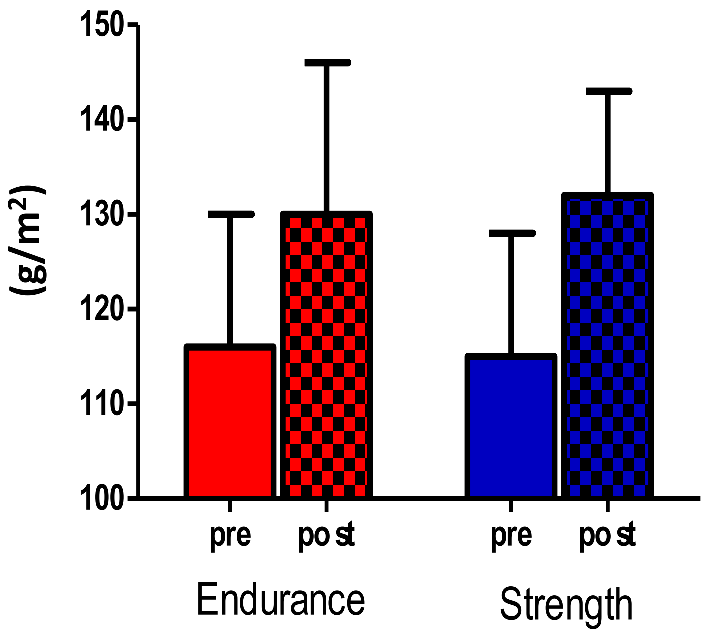
SEP = 200 ms / DFP = 175 ms

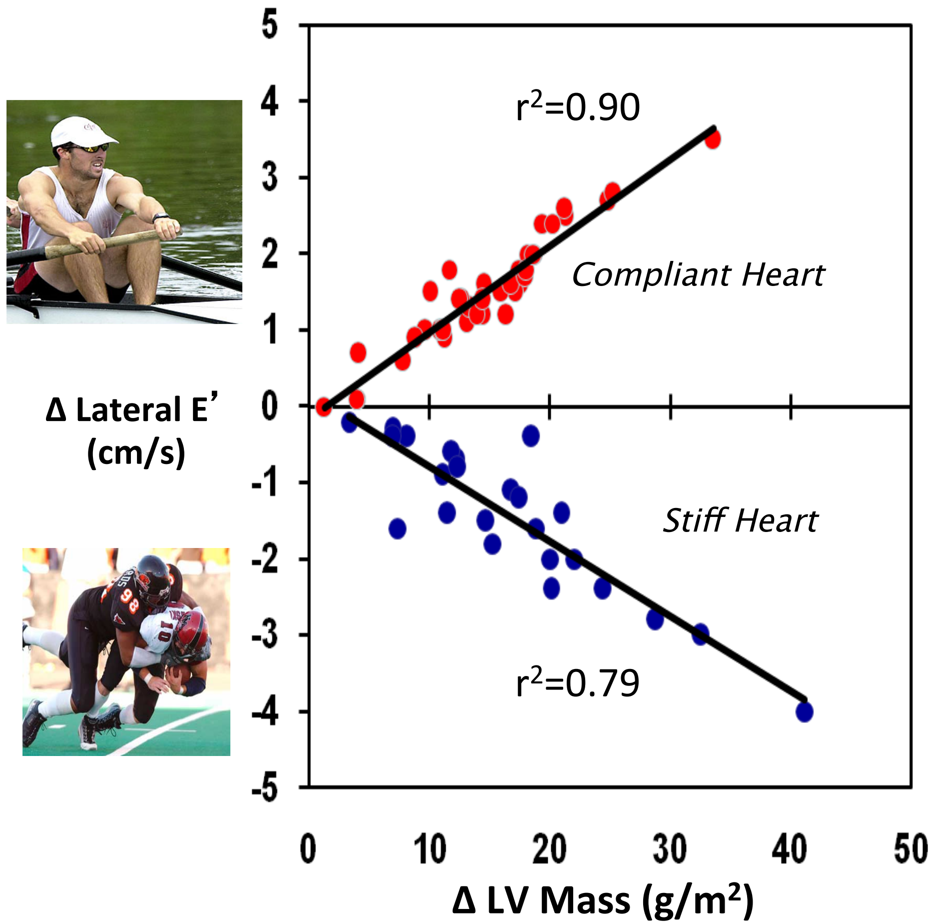
Endurance: LV Filling

Cardiovascular Performance Program

LV Hypertrophy & Diastolic Function

Δ Left Ventricular Mass





J Appl Physiol 2008;104:1121

Endurance: LV Filling

Cardiovascular Performance Program

JACC: CARDIOVASCULAR IMAGING
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DOI:10.1016/j.jcmg.2010.08.003

The Impact of Endurance Exercise Training on Left Ventricular Torsion

Rory B. Weiner, MD,* Adolph M. Hutter, Jr., MD,* I
Jonathan Kim, MD,* Arthur E. Weyman, MD,* Maliss
Michael H. Picard, MD,* Aaron L. Baggish, MD*
Boston, Massachusetts

OBJECTIVI
systolic left ver

BACKGROU
LVT, a recogniz
the setting of
training on LVT

METHODS
training on LV
Conventional L
diastolic UTR w
the EET study p

RESULTS
diastolic volum
vs. 115.7 ± 12
(8.9 ± 4.2° vs.
significant incr
of EET on LV
(−110.6 ± 41.8
the end of isov
increased LV end-
101.3 ± 11.4 g/m²
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CONCLUSI
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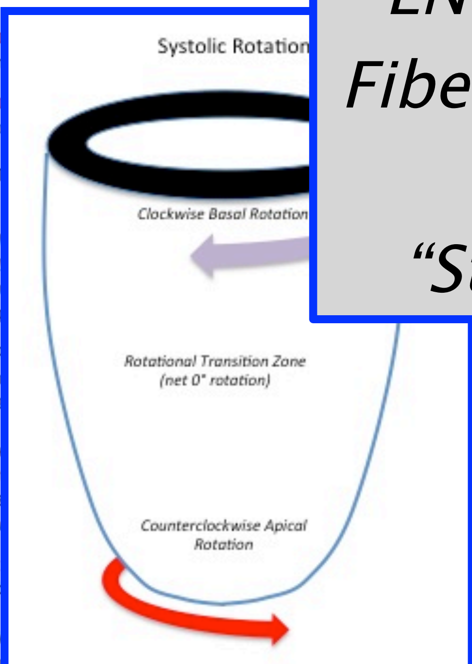


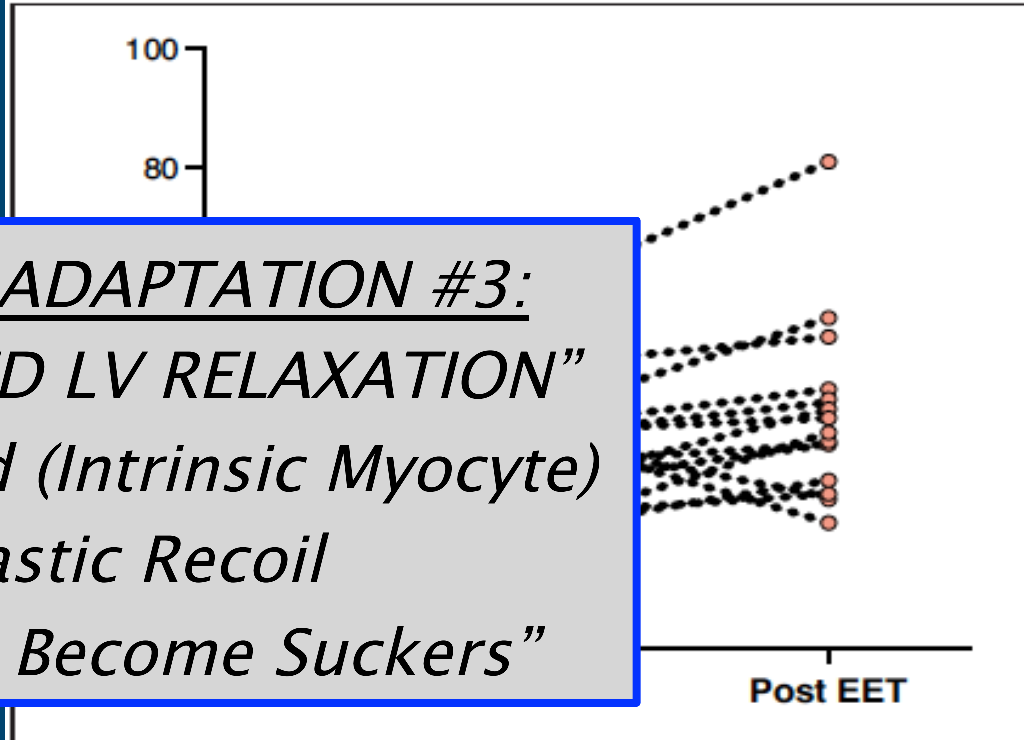


Figure 4. The Percentage of Untwisting by the End of the IVRT

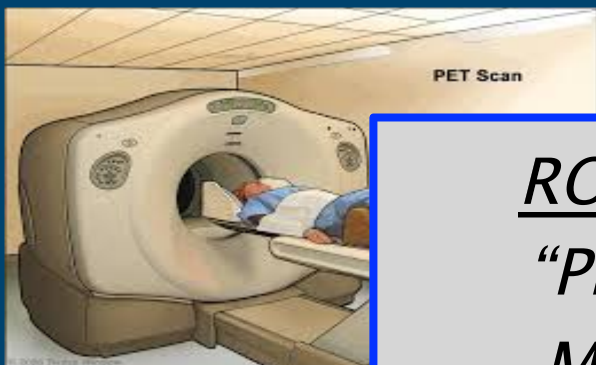
There was a significant increase in the percentage (%) of untwisting that occurred by the end of the isovolumic relaxation time (IVRT) (31.2 ± 12.0% vs. 39.9 ± 14.9%, $p = 0.04$). This percentage increased in 13 of 15 subjects. EET = endurance exercise training.

__ROWING ADAPTATION #3:__
"ENHANCED LV RELAXATION"
Fiber Speed (Intrinsic Myocyte)
Elastic Recoil
"Strokers Become Suckers"

Endurance: Myocardial Energetics

MGH 1811 Cardiovascular Performance Program

Big Hearts = Inefficient Hearts....?



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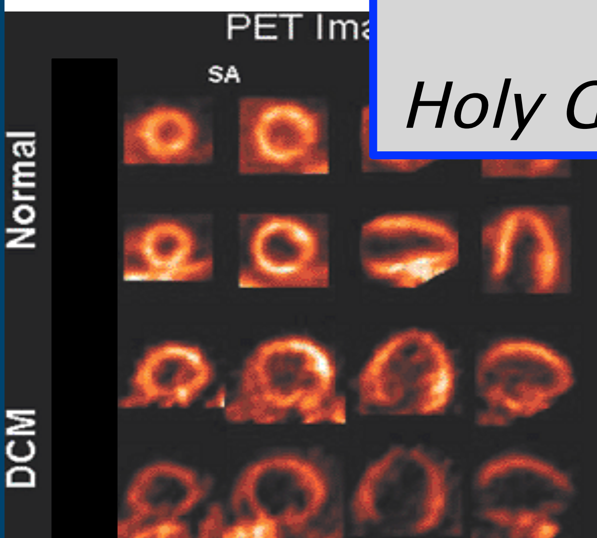
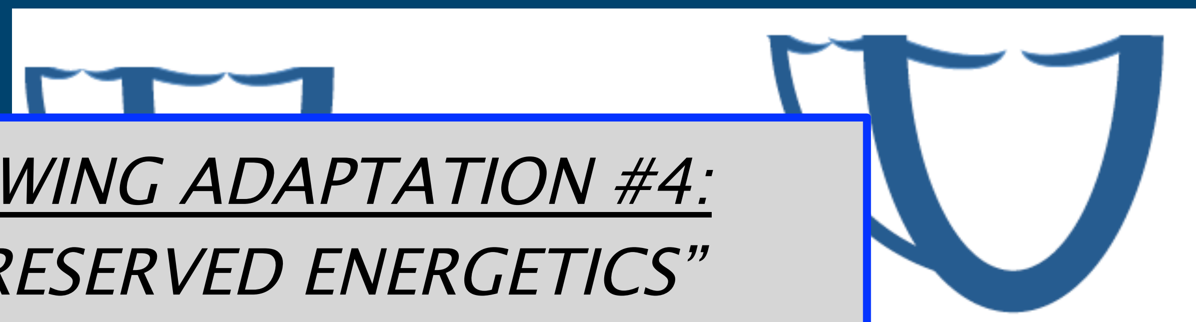
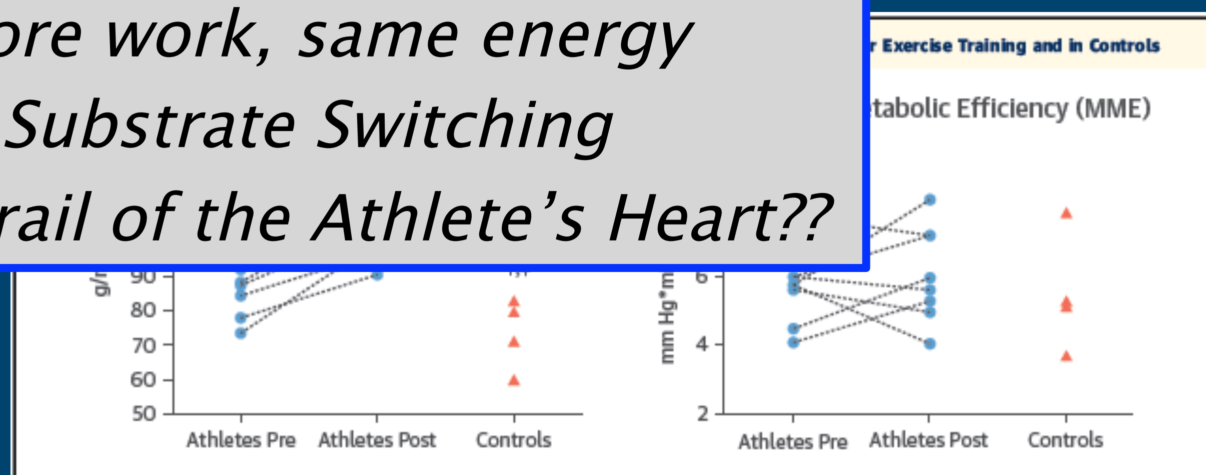






*p < 0.05 athletes pre-training versus post-training. †p < 0.05 athletes pre-training versus controls. ‡p < 0.05 athletes post-training versus controls. LV = left ventricular.

<u>ROWING ADAPTATION #4:</u>

"PRESERVED ENERGETICS"

More work, same energy

Substrate Switching

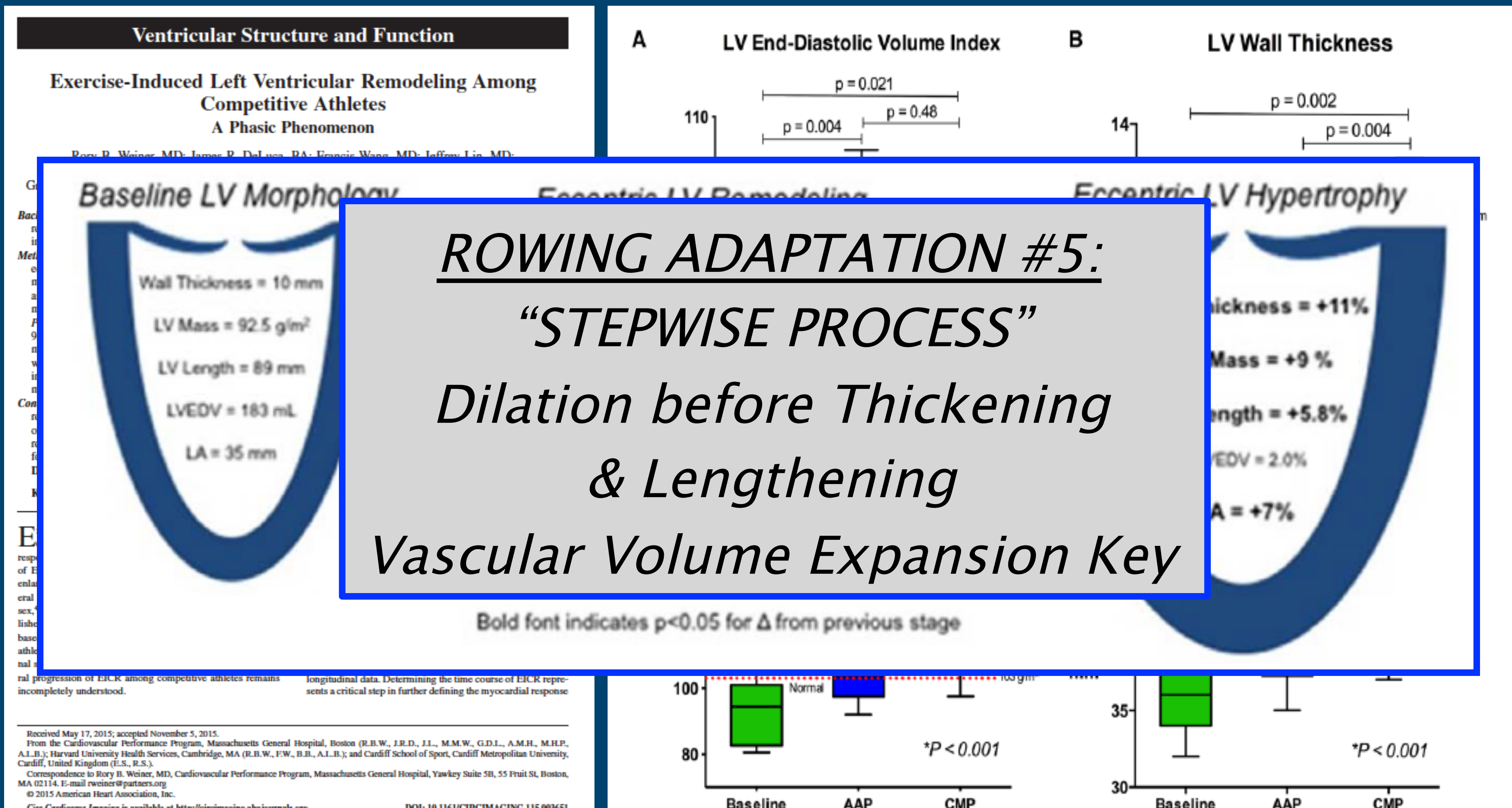
Holy Grail of the Athlete's Heart??

Wasfy et a. JACC Imaging 2018

Endurance: Remodeling Time Line?

Cardiovascular Performance Program

Nothing Happens Overnight.... Discrete Steps?



<u>*ROWING ADAPTATION #5:*</u>

"STEPWISE PROCESS"

Dilation before Thickening

& Lengthening

Vascular Volume Expansion Key

Endurance: Remodeling vs. Skill Level

Cardiovascular Performance Program

Differences in Cardiac Parameters among Elite Rowers and Subelite Rowers

AARON L. BAGGISH[1], KIBAR YARED[1], RORY B. WEINER[1], FRANCIS WANG[2], ROBERT DEMES[3], MICHAEL H. PICARD[1], FREDRICK HAGERMAN[4], and MALISSA J. WOOD[1]

[1]*Division of Cardiology, Massachusetts General Hospital, Boston, MA;* [2]*Harvard University Health Services, Cambridge, MA;* [3]*United States Army Research Institute for Environmental Medicine, Natick, MA; and* [4]*Department of Biomedical Sciences, Ohio University, Athens, OH*

ABSTRACT

BAGGISH, A. L., K. YARED, R. B. WEINER, F. WANG, R. DEMES, M. H. PICARD, F. HAGERMAN, and M. J. WOOD. Differences in Cardiac Parameters among Elite Rowers and Subelite Rowers. *Med. Sci. Sports Exerc.*, Vol. 42, No. 6, pp. 1215–1220, 2010. There is significant individual variability in the cardiac adaptation that occurs in response to exercise training. Factors associated with this variability remain incompletely und
their underlying cardiac parameters has
cardiac structure and function differ sig
controls (C). **Methods:** Cardiac parame
Doppler, and speckled-tracking echoc
evidenced by the significant difference
with C. When compared with SR, ER w
$P = 0.02$), LV mass (150 ± 11 vs 134 ±
vs 13.9 ± 1.5 cm²·m⁻², $P < 0.001$). Fu
36% ± 7% vs 31% ± 6%, $P = 0.008$)
the RV (A′ = 6.6 ± 1.4 vs 4.3 ± 1.3
specific aspects of cardiac structure a
Key Words: EXERCISE-INDUCED
FUNCTION, DIASTOLIC FUNCTION

Exercise training leads to adaptive
structure and function. Left vent
trophy and dilation (6,26), righ
dilation (9,35), and left atrial enlargemen
demonstrated in trained athletes. Recently
in cardiac function have also been repo
examination of the extensive prior c
(27,30,31,36) and recent longitudinal st
onstrate significant interindividual varia
structural and functional response to
contributory factors including age (32),
type (21,39), ethnicity (5), and gene p

has been demonstrated in elite, subelite, and recreational athletes, we are unaware of any prior studies that provide a direct comparison of single-sport athletes at different competitive levels. We hypothesized that elite competitive rowers (ER) would have significant cardiac differences, including ventricular chamber dimensions, mass, and diastolic function, when compared with rowers participating at a lower competition level. To test this hypothesis, we conducted a comparative analysis of ER, subelite competitive rowers (SR), and sedentary controls. The primary objective of this study was to determine which structural and

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DOI: 10.1249/MSS.0b013e3181c81604

Demographics and Clinical Parameters	ER (n = 20)	SR (n = 20)
Age (yr)	25 ± 3*,†	20 ± 2
Height (cm)	197 ± 5*,†	186 ± 6†
Weight (kg)	98 ± 5*,†	82 ± 10
BSA	2.3 ± 0.1*,†	2.1 ± 0.2
Resting pulse (beats·min⁻¹)	56 ± 7†	60 ± 5†
Systolic blood pressure (mm Hg)	124 ± 10	118 ± 11
Diastolic blood pressure (mm Hg)	62 ± 9†	58 ± 9†
Family hypertension history	4/20	5/20
Prescription medication use	8/20	5/20
Cardiovascular medication	0/20	0/20
Noncardiovascular medication	8/20	5/20
		11 ± 4†
		9 ± 2†
		2 ± 1
		5 ± 2†

			SR (n = 20)
			62 ± 13†
			10.6 ± 0.7†
PWT (mm)	<11	[illegible]	10.5 ± 0.6†
LVEDV (mL)	67–155	171 ± 20*,†	140 ± 20†
LVESV (mL)	22–58	74 ± 12*,†	60 ± 8†
LV mass (g)	88–224	332 ± 45*,†	267 ± 31†
RVIDd (mm)	27–33	47 + 4*,†	42 ± 5†
RV diastolic area (cm²)	11–28	36 ± 3*,†	28 ± 4†
RV systolic area (cm²)	7.5–16	18 ± 3*,†	15 ± 3†

ROWING ADAPTATION #6:

COMPETITION LEVEL MATTERS

Genetics (Baseline & Plasticity)

Chronic Training Stimulus Dose

What You See Depends on Who You Study

Key CV Controversies

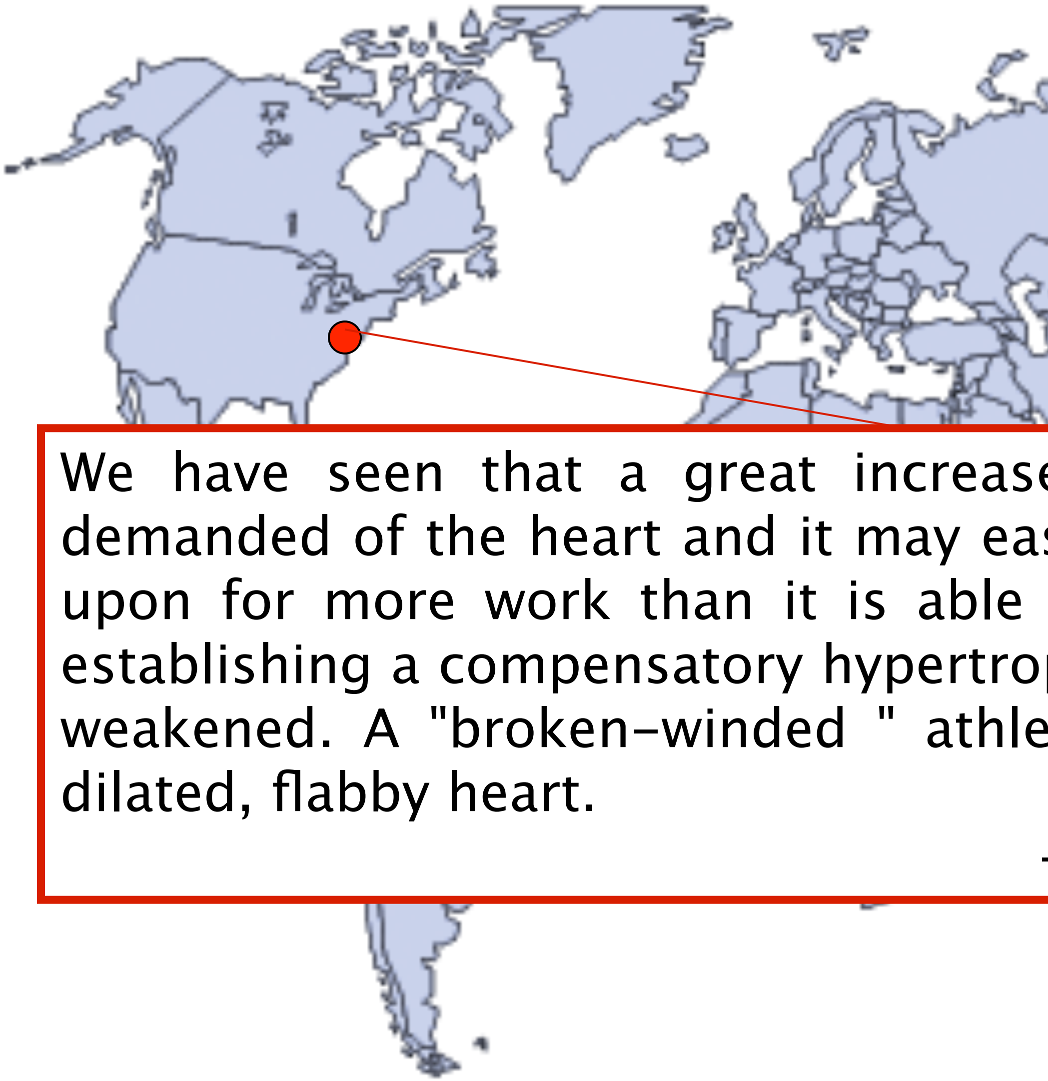
Cardiovascular Performance Program

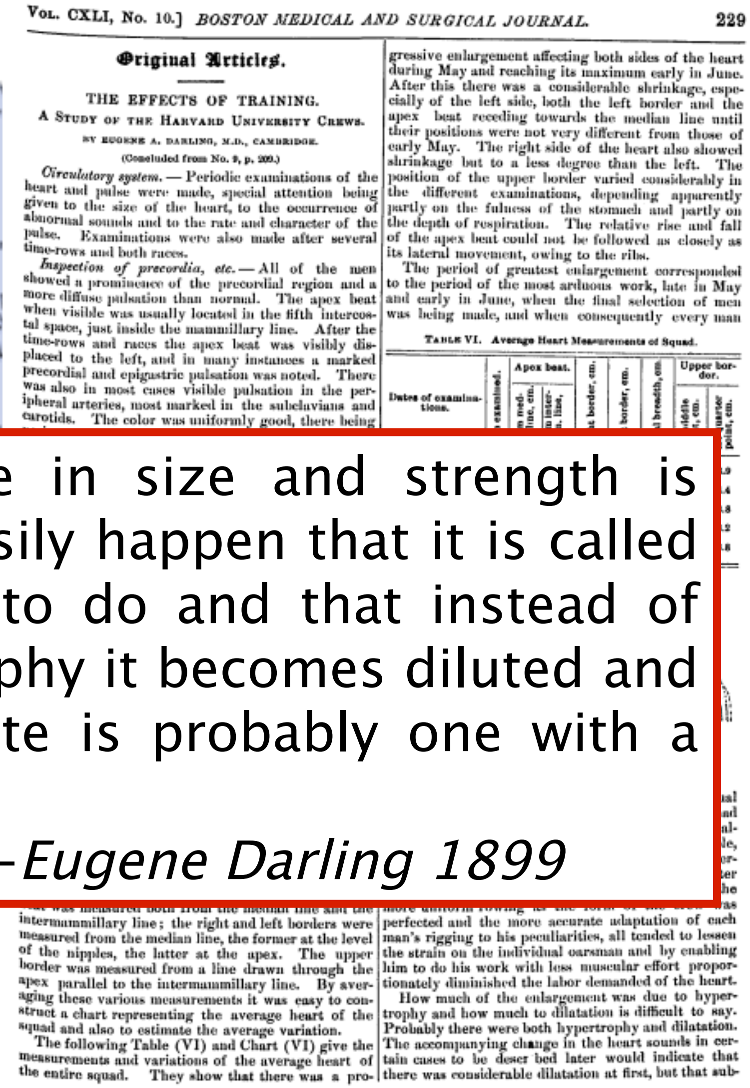
SO FAR SO GOOD.....

BUT, Can you get too much of a good thing??

Athlete's Heart: *The Beginnings…*

Cardiovascular Performance Program





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Original Articles.

THE EFFECTS OF TRAINING.

A Study of the Harvard University Crews.

By Eugene A. Darling, M.D., Cambridge.

(Concluded from No. 9, p. 209.)

Circulatory system. — Periodic examinations of the heart and pulse were made, special attention being given to the size of the heart, to the occurrence of abnormal sounds and to the rate and character of the pulse. Examinations were also made after several time-rows and both races.

Inspection of precordia, etc. — All of the men showed a prominence of the precordial region and a more diffuse pulsation than normal. The apex beat when visible was usually located in the fifth intercostal space, just inside the mammillary line. After the time-rows and races the apex beat was visibly displaced to the left, and in many instances a marked precordial and epigastric pulsation was noted. There was also in most cases visible pulsation in the peripheral arteries, most marked in the subclavians and carotids. The color was uniformly good, there being

…

intermammillary line; the right and left borders were measured from the median line, the former at the level of the nipples, the latter at the apex. The upper border was measured from a line drawn through the apex parallel to the intermammillary line. By averaging these various measurements it was easy to construct a chart representing the average heart of the squad and also to estimate the average variation.

The following Table (VI) and Chart (VI) give the measurements and variations of the average heart of the entire squad. They show that there was a pro-

gressive enlargement affecting both sides of the heart during May and reaching its maximum early in June. After this there was a considerable shrinkage, especially of the left side, both the left border and the apex beat receding towards the median line until their positions were not very different from those of early May. The right side of the heart also showed shrinkage but to a less degree than the left. The position of the upper border varied considerably in the different examinations, depending apparently partly on the fulness of the stomach and partly on the depth of respiration. The relative rise and fall of the apex beat could not be followed as closely as its lateral movement, owing to the ribs.

The period of greatest enlargement corresponded to the period of the most arduous work, late in May and early in June, when the final selection of men was being made, and when consequently every man

Table VI. Average Heart Measurements of Squad.

Dates of examinations.	[illegible] examined.	Apex beat.		[illegible] border, cm.	[illegible] border, cm.	[illegible] breadth, cm.	Upper border.	
		[illegible] median line, cm.	[illegible] inter-[illegible] line,				[illegible] middle [illegible], cm.	[illegible] quarter point, cm.

…

more uniform rowing … was perfected and the more accurate adaptation of each man's rigging to his peculiarities, all tended to lessen the strain on the individual oarsman and by enabling him to do his work with less muscular effort proportionately diminished the labor demanded of the heart.

How much of the enlargement was due to hypertrophy and how much to dilatation is difficult to say. Probably there were both hypertrophy and dilatation. The accompanying change in the heart sounds in certain cases to be deser bed later would indicate that there was considerable dilatation at first, but that sub-

We have seen that a great increase in size and strength is demanded of the heart and it may easily happen that it is called upon for more work than it is able to do and that instead of establishing a compensatory hypertrophy it becomes diluted and weakened. A "broken-winded " athlete is probably one with a dilated, flabby heart.

–*Eugene Darling 1899*

Cardiomyopathy

Cardiovascular Performance Program

The impact of endurance exercise training on left ventricular systolic mechanics

Aaron L. Baggish,[1] Kibar Yared,[1] Francis Wang,[2] Rory B. Weiner,[1] Adolph M. Hutter Jr.,[1] Michael H. Picard,[1] and Malissa J. Wood[1]

[1]*Division of Cardiology, Massachusetts General Hospital, Boston, Massachusetts; and* [2]*University Health Services, Harvard University, Cambridge, Massachusetts*

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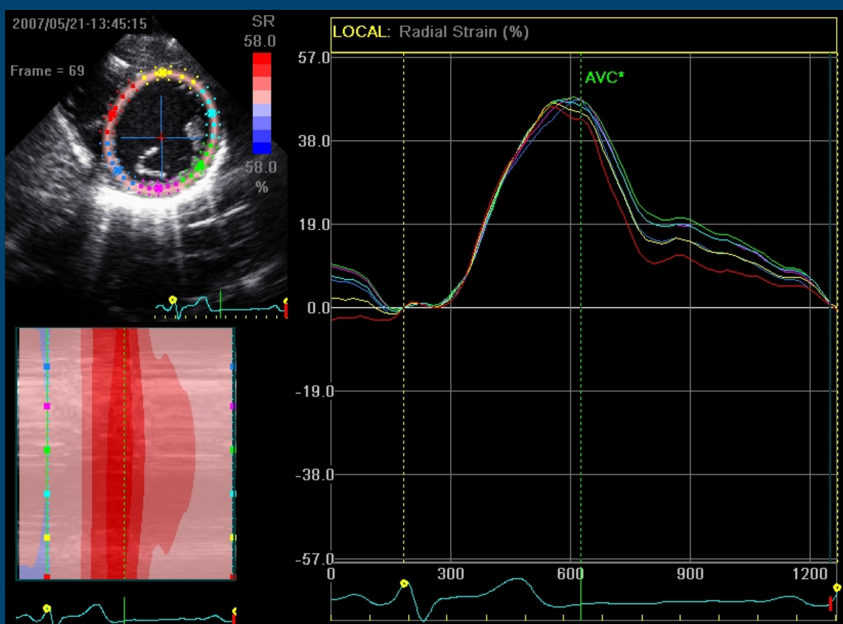


Harvard Athlete Initiative

Cardiomyopathy

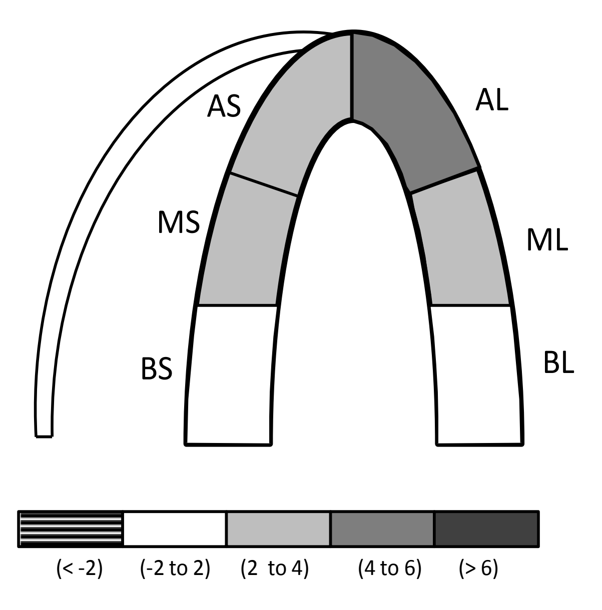
Cardiovascular Performance Program

Am J Physiol Heart Circ Physiol 295: H1109–H1116, 2008.
First published July 11, 2008; doi:10.1152/ajpheart.00395.2008.

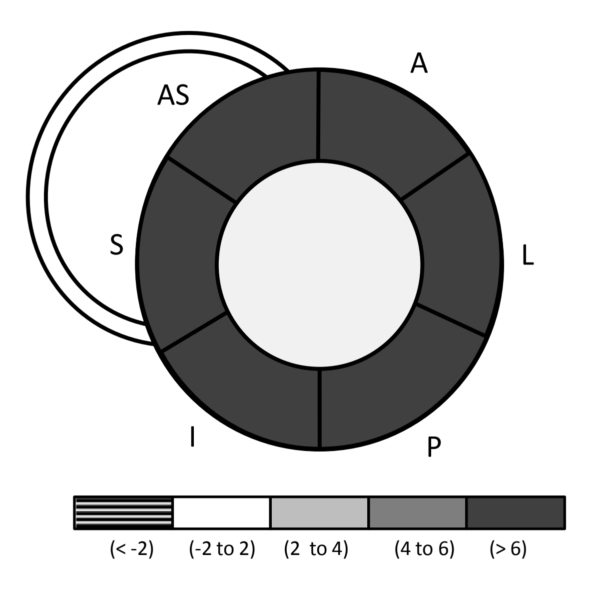
The impact of endurance exercise training on left ventricular systolic mechanics

Aaron L. Baggish,[1] Kibar Yared,[1] Francis Wang,[2] Rory B. Weiner,[1] Adolph M. Hutter Jr.,[1] Michael H. Picard,[1] and Malissa J. Wood[1]

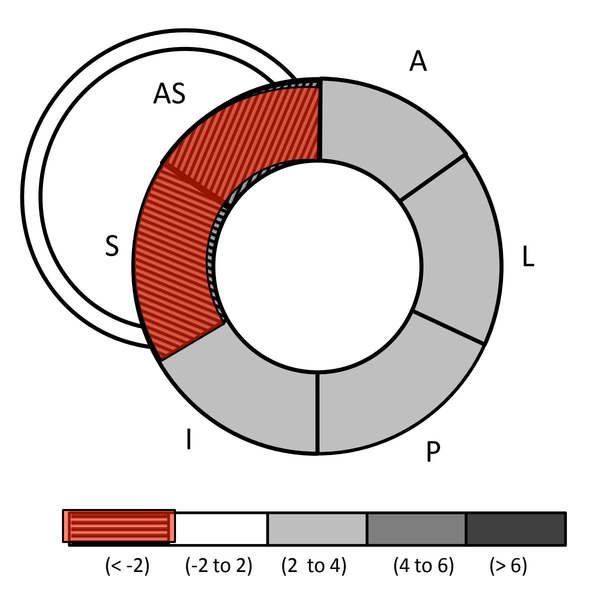
LV Systolic Strain Changes with Rowing Training (n=20)



Longitudinal ~ ⇧20–25%



Radial ~ ⇧50–60%

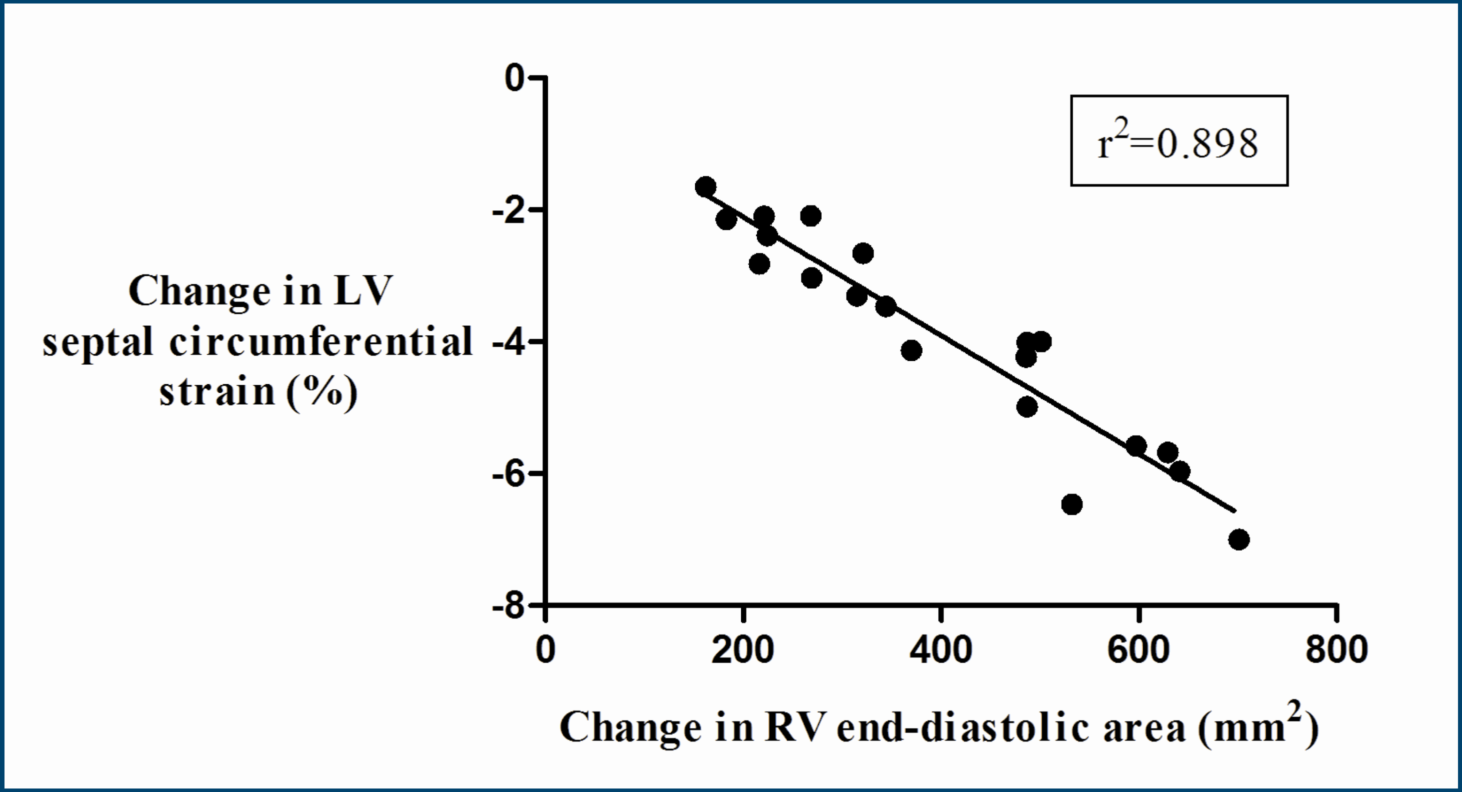


Circumferential ~ ⇩20–25%

Normal to Supranormal Strain….Focal Septal Dysfunction Fatigue??

Cardiomyopathy

The Ventricular Interdependence of Physiologic Remodeling



Am J Physiol Heart Circ Physiol 2008;295:1109

Cardiomyopathy

Cardiovascular Performance Program

MGH 1811

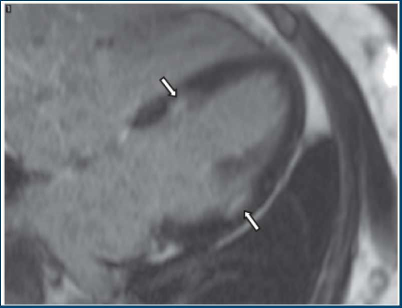
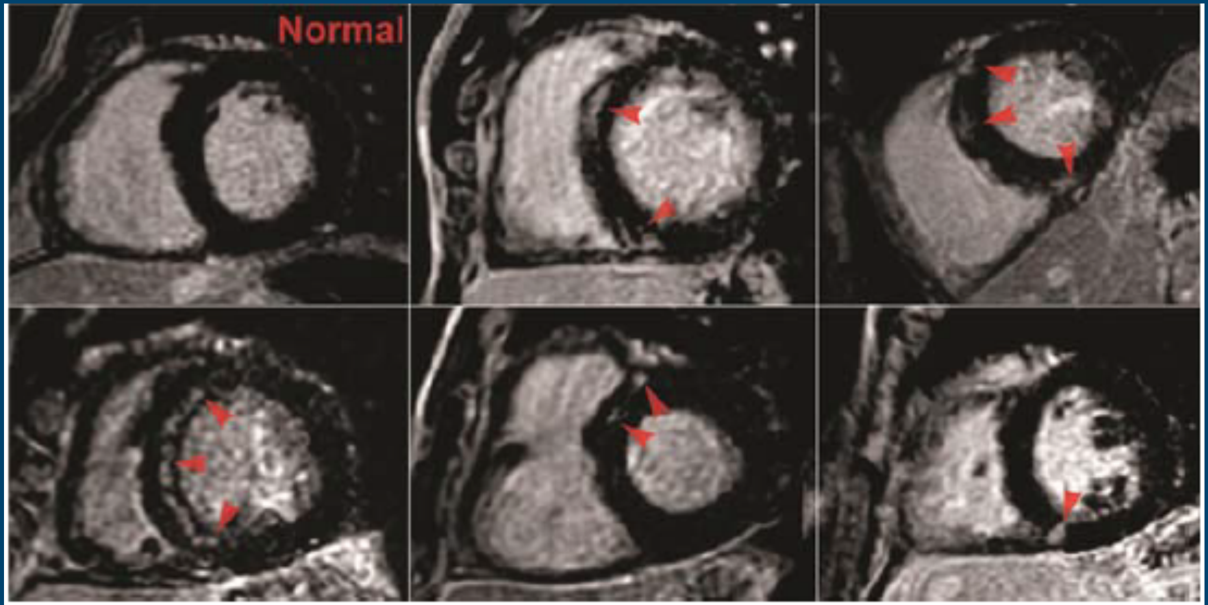


Table 3. *Location and extent of LGE in veteran athletes*

Participant No.	Age, yr	Percentage of Total LGE Mass, g	LGE Pattern	Perfusion Defect	Interpretation	Location
1	67	18.9	CAD	Yes	Probable dual infarction	Septal and lateral wall
2	50	8	Non-CAD	No	Probable myocarditis	Epicardial lateral wall
3	66	3	Non-CAD	No	Nonspecific	Basal and midinsertion point
4	60	3	Non-CAD	No	Nonspecific	Inferior insertion point mid and apical
5	50	1	Non-CAD	No	Nonspecific	Insertion point inferior mid/apical
6	51	1	Non-CAD	No	Nonspecific	Inferior insertion point

Whyte et al. JAP 2011



LaGerche et al. EHJ 2011

Cardiomyopathy

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Exercise-induced right ventricular dysfunction and structural remodelling in endurance athletes

André La Gerche[1,2*], Andrew T. Burns[3], Don J. Mooney[3], Warrick J. Inder[1], Andrew J. Taylor[4], Jan Bogaert[5], Andrew I. MacIsaac[3], Hein Heidbüchel[2], and David L. Prior[1,3]

Table 1 Baseline demographic and functional measures according to the endurance event completed

	Overall	Marathon run	Endurance triathlon[a]	Alpine cycling	Ultra triathlon[a]	P-value
Number of athletes	40	7	11	9	13	
Race distance (km)		42.2	1.9/90/21.1	207	3.8/180/42.2	
Race completion time		2 h 59 min ± 30 min	5 h 24 min ± 25 min	8 h 5 min ± 42 min	10 h 52 min ± 1 h 16 min	
Ambient temperature (°C)		16–20	18–31	24–34	17–28	
Age (years)	37 ± 8	38 ± 3	33 ± 7	44 ± 9	34 ± 8	0.014
Male (%)	90	86	91	78	100	0.378
BMI (kg/m^2)	23.6 ± 1.9	22.3 ± 1.6	24.0 ± 2.1	23.9 ± 2.1	23.5 ± 1.3	0.306
% of predicted VO_2max	146 ± 18	142 ± 8	141 ± 20	154 ± 20	148 ± 18	0.36
Training (years)	10 ± 9	13 ± 8	6 ± 5	12 ± 14	11 ± 9	0.277
Training (h/week)	16.3 ± 5.1	14 ± 6	14 ± 3	13 ± 4	21 ± 5	<0.0001

Cardiomyopathy

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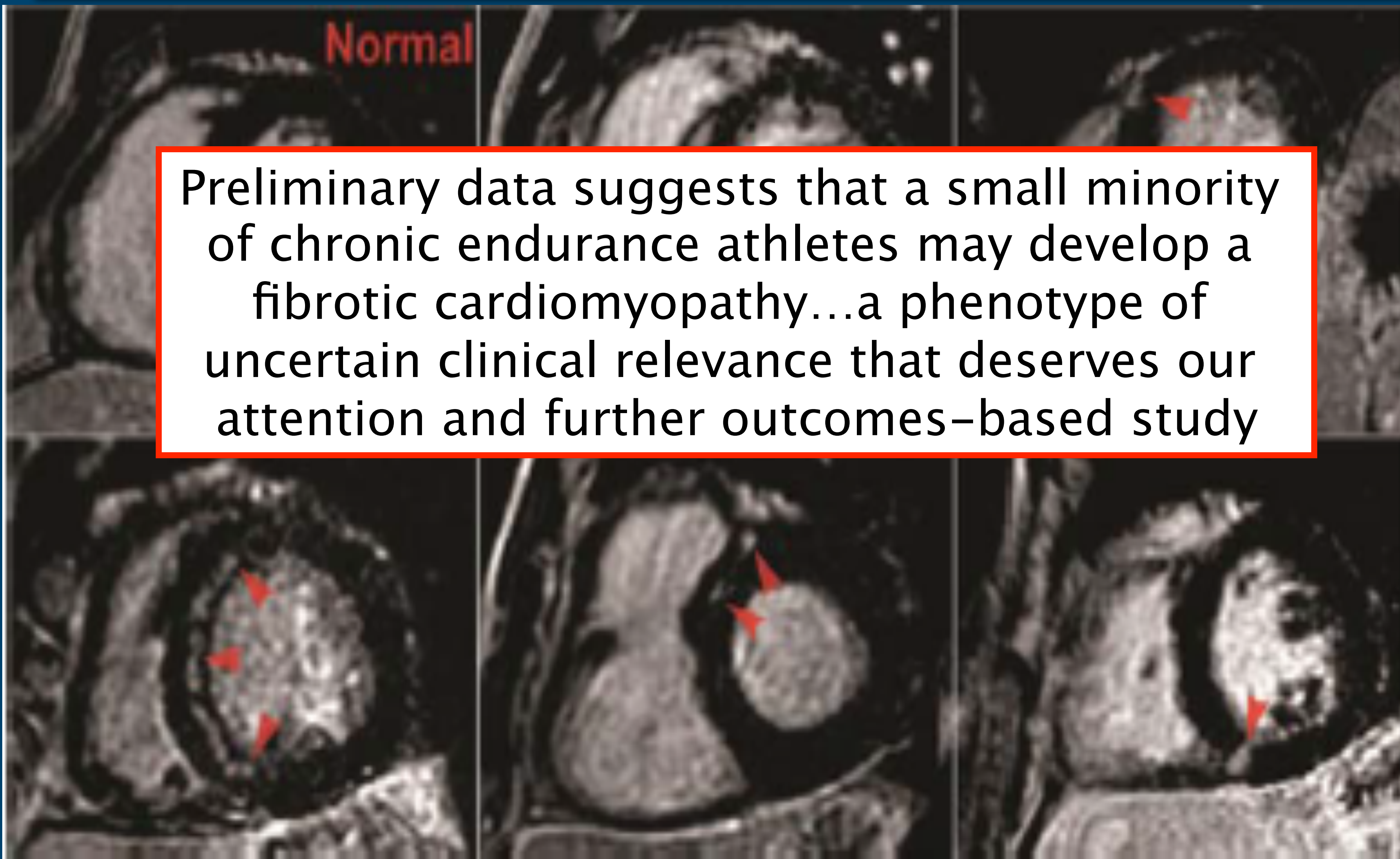


Preliminary data suggests that a small minority of chronic endurance athletes may develop a fibrotic cardiomyopathy…a phenotype of uncertain clinical relevance that deserves our attention and further outcomes-based study

Exercise Cardiomyopathy ?

Cardiovascular Performance Program

Chronic Extreme Volume & Intensity

+

Training / Recovery Mismatch

+

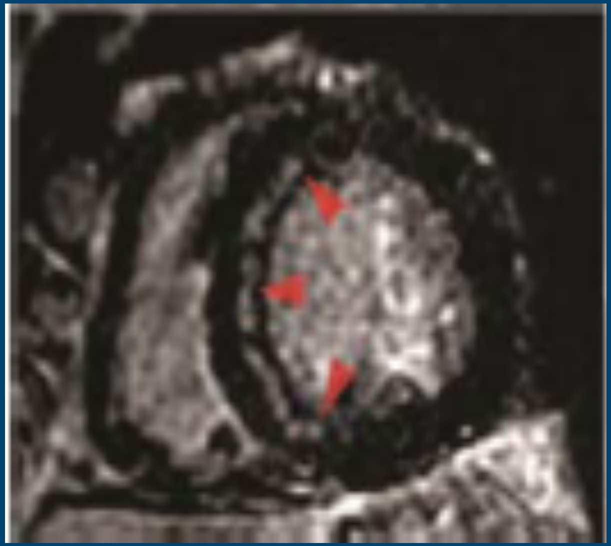
Host Susceptibility (Genetics)

+

Secondary Process (Drugs, Infection, Disease)

A Theoretical Pathogenic Cascade

"The Perfect Storm"



Summary

Key Cardiac Adaptations in Rowers:

1.) Bi-ventricular growth (Ecc.-LVH)

2.) Enhanced filling capacity (High HR)

3.) Preserved energetics

4.) Phasic remodeling process

5.) Competition level-specific phenotype

6.) Fatigable... Injury prone with overuse??

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