The Athletic Heart Takes Shape: Overview of Cardiac Remodeling

Rory B. Weiner, MD

Cardiovascular Performance Program, MGH

Assistant Professor of Medicine, Harvard Medical School

Athlete's Heart

- Outline
  - Exercise-induced Cardiac Remodeling
  - Health vs. Disease
    - LV chamber enlargement
    - RV chamber enlargement
    - LV wall thickening

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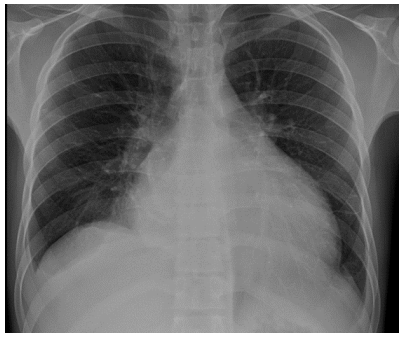
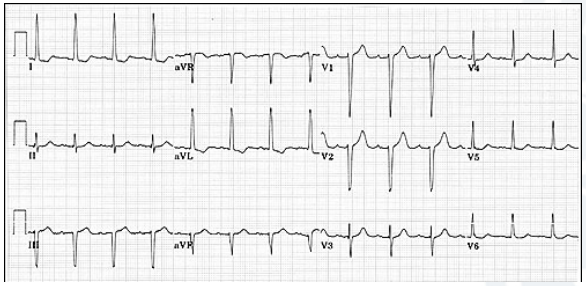
Historical Overview

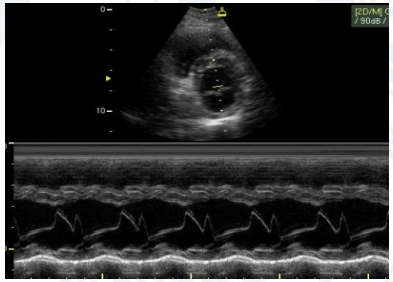
1899: Initial observations by Henschen and Darling

- Cardiac enlargement by physical exam

100+ years of scientific study:







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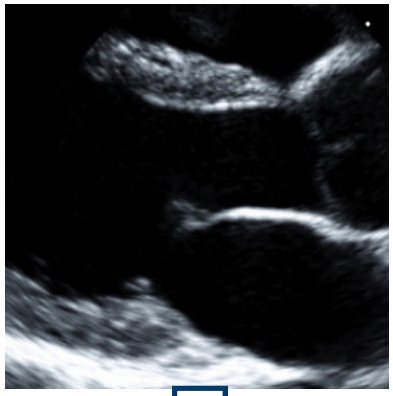
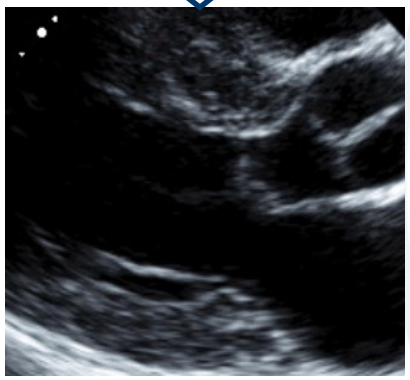
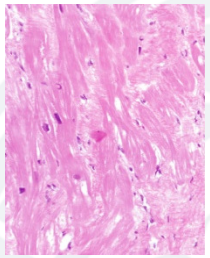
Cardiac Remodeling

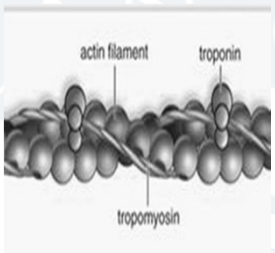
Hemodynamic Stress of Sport





Pathophysiology of Disease





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Cardiac Remodeling: *Exercise*

Endurance Activities (Isotonic)

Sustained ↑ CO

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

Volume Challenge

Strength Activities (Isometric)

Repetitive↑ SBP

- Systolic BP > 200 mmHg
- Skeletal Muscle Contraction
- Vasoconstriction

Pressure Challenge

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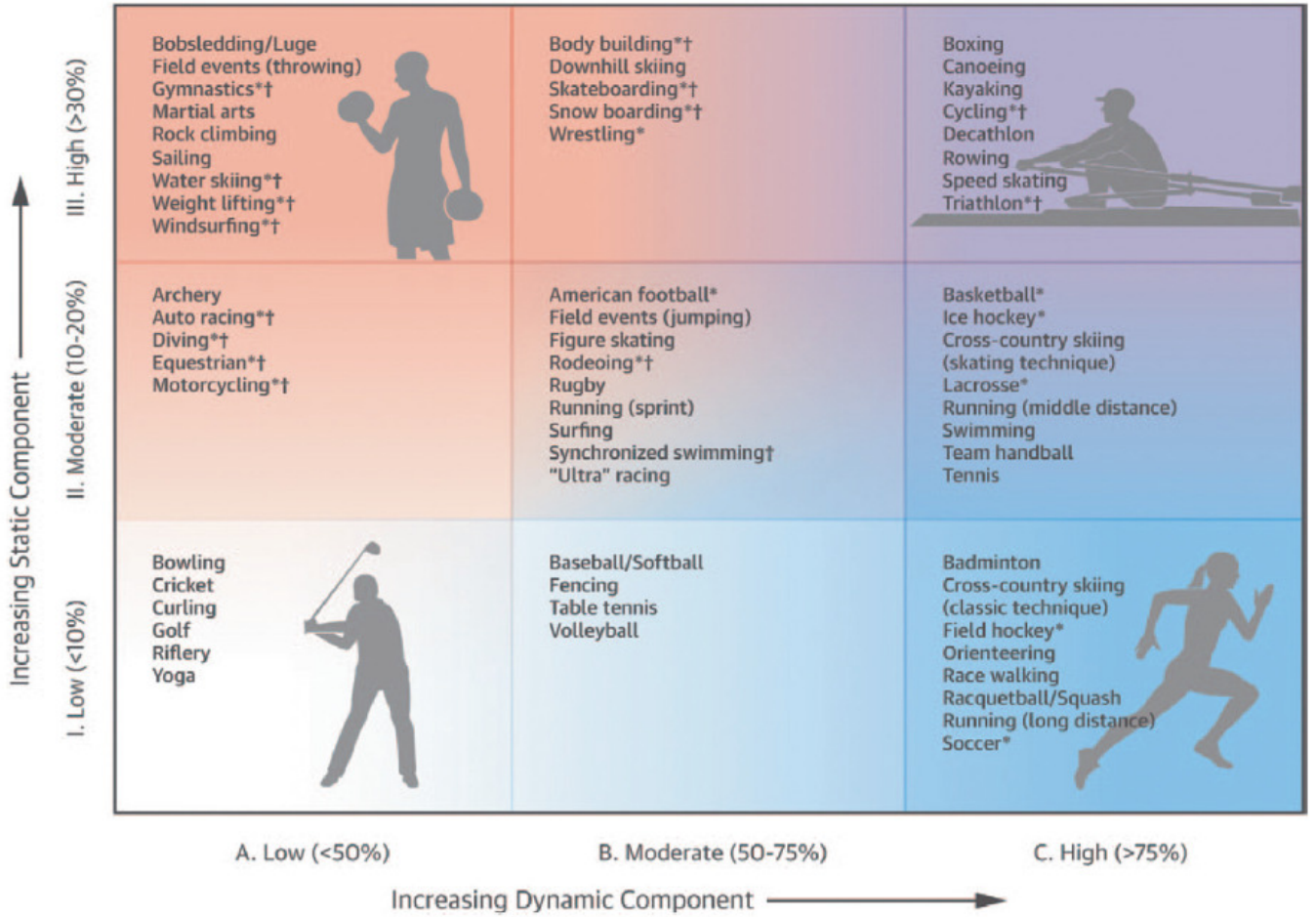
FIGURE Classification of Sports



Levine et al
JACC 2015

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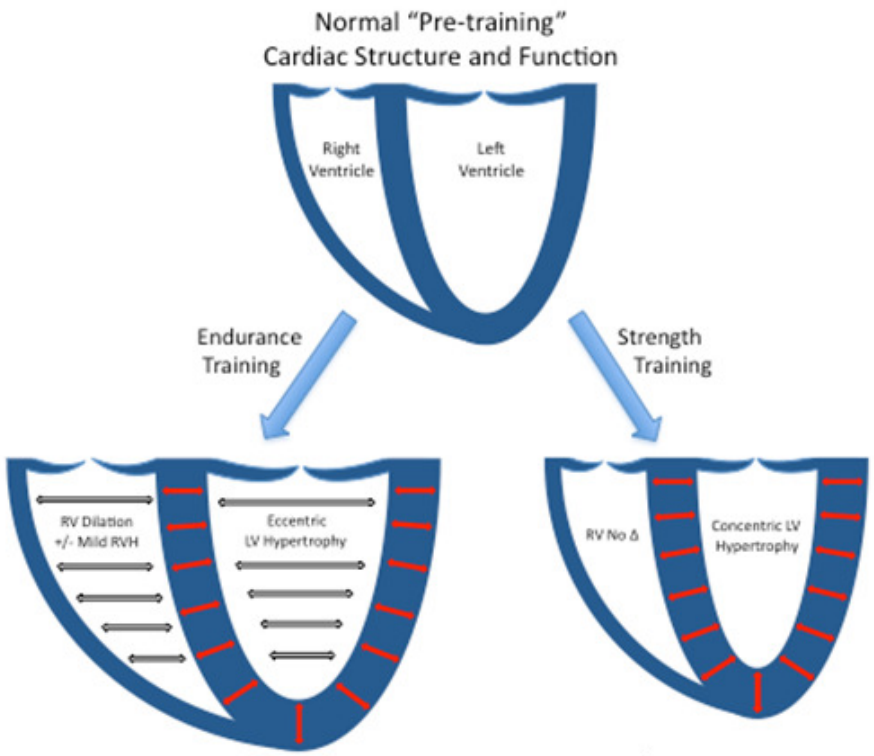

Characteristic Features

-Eccentric LVH and RV dilation
-Biatrial enlargement
-Normal to slightly reduced resting LVEF
-Normal or enhanced early diastolic function

Characteristic Features

-Concentric LVH
-Enlarged left atrium
-Hyperdynamic resting LVEF
-Reduced early diastolic function
-Altered LV mechanics

Weiner & Baggish. *Prog Cardiovasc Dis* 2012;54:380.

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Determinants of Myocardial Adaptation

- Sporting discipline
- Gender
  - Females < males
- Ethnicity
  - ↑ wall thickness in Afro-Caribbean descent
- Genetics / Molecular pathways
- Exercise exposure duration and “dose”

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Health vs. Disease

- Can we separate athletic remodeling from pathology?
  - Yes, the majority of the time when a systematic approach is used.

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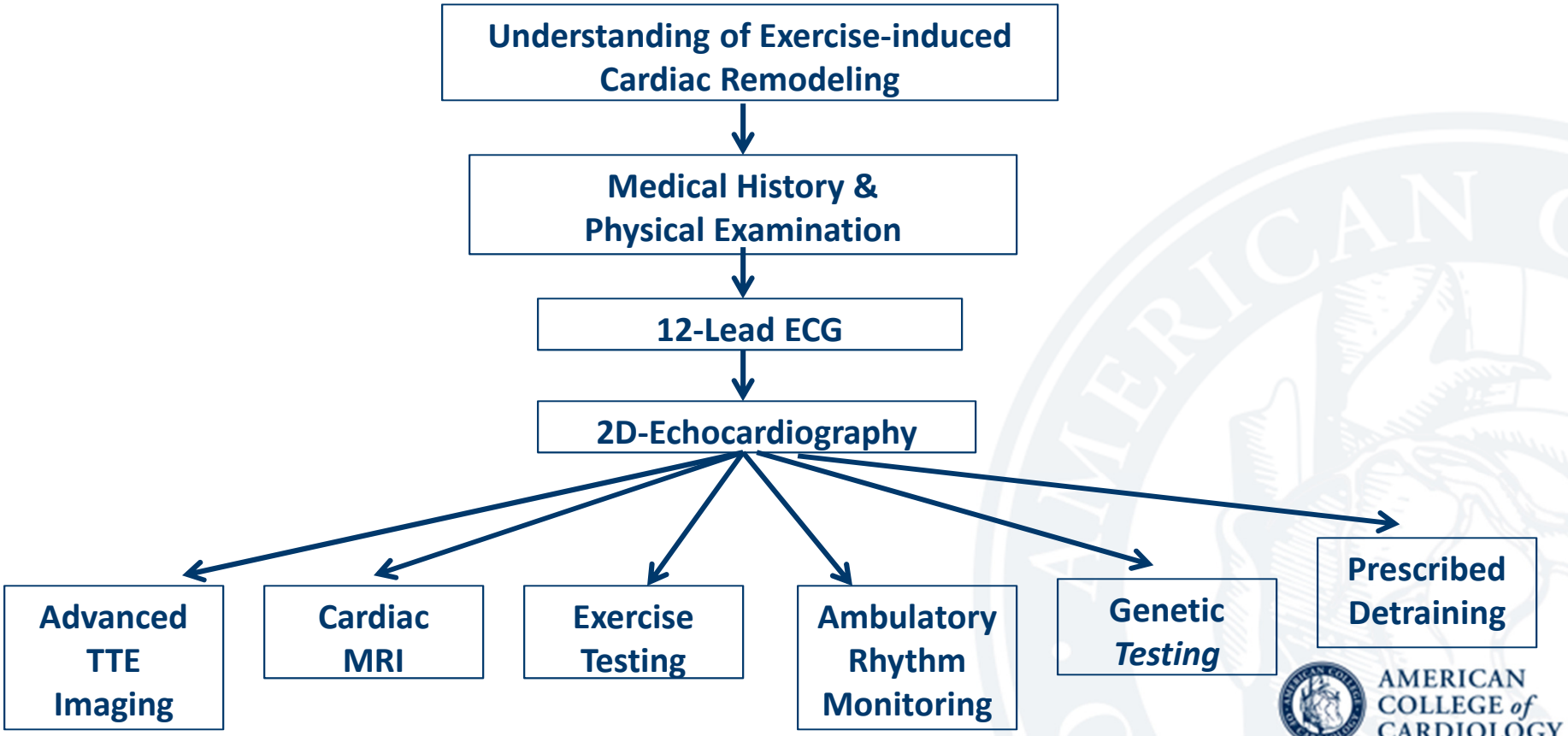
Evaluation "Tool Kit"



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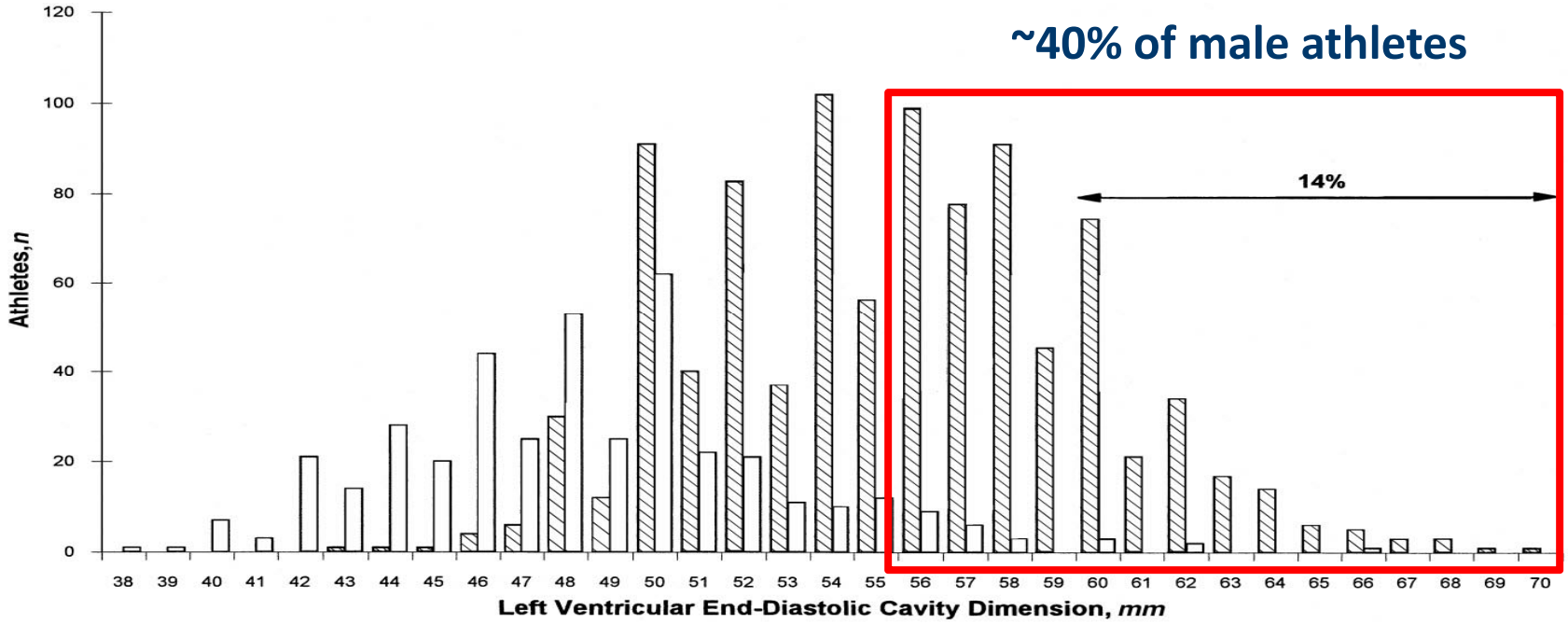
LV Chamber Enlargement



Pelliccia et al. *Ann Intern Med* 1999;130:23.

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LV Chamber Enlargement

Table 4 Echocardiographic findings from the study population of university athletes

Parameter	Male (n = 300)		Female (n = 197)	
	Normal (n = 209)	Physiologic remodeling (n = 91)	Normal (n = 178)	Physiologic remodeling (n = 19)
Structural parameters				
Interventricular septal thickness (mm)	9.8 ± 0.9	11.6 ± 0.5	8.3 ± 0.7*	10.6 ± 0.5†
LV posterior wall thickness (mm)	10.0 ± 1.2	11.8 ± 1.4	8.6 ± 1.1*	10.7 ± 0.7†
LV inner dimension at end-diastole (mm)	51 ± 3	57 ± 5	42 ± 4*	54 ± 4†
LA diameter (mm)	36 ± 4	40 ± 4	32 ± 3*	38 ± 4
RV end-diastolic diameter (mm)	30 ± 5	36 ± 3	28 ± 4*	33 ± 3†
Functional parameters				
LV ejection fraction (%)	65 ± 7	58 ± 4	68 ± 6	64 ± 6†
Transmitral E wave (cm/sec)	86 ± 16	96 ± 13	81 ± 17	88 ± 12
Tra				
E′ l				
E′ s				
A′ l				
A′ s				

LA, L
Data

*P < .05 for comparison with male athletes in the normal cardiac structure and function group.
†P < .05 for comparison with male athletes in the physiologic remodeling group.

25% of US college athletes
exceed gender recommended LVIDd limit

Weiner et al. *J Am Soc Echocardiogr* 2012;25:568.

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- *Physiologic LV Chamber Enlargement:*
  - Expected with endurance training.
  - Accompanied by proportionate increase in wall thickening (Eccentric LVH).
  - Accompanied by normal to low normal resting LVEF (~50%).
  - TDI / Strain assessment with preserved or enhanced function.
  - Accompanied by "other" chamber enlargement (RV, LA).
  - LVIDd "cut-offs" are not helpful.
  - When in doubt, exercise testing is very useful (confirm LV augmentation and document supranormal exercise capacity).

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RV Chamber Enlargement

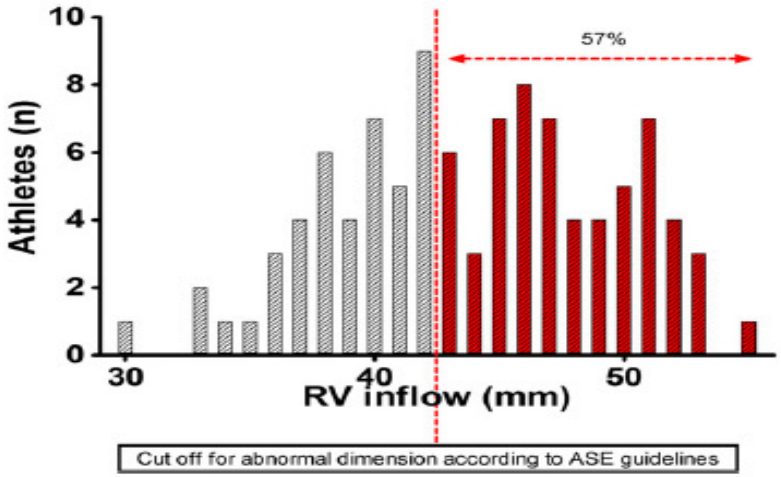

Figure 2 Range of values for RV inflow dimension in endurance athletes (n = 102).

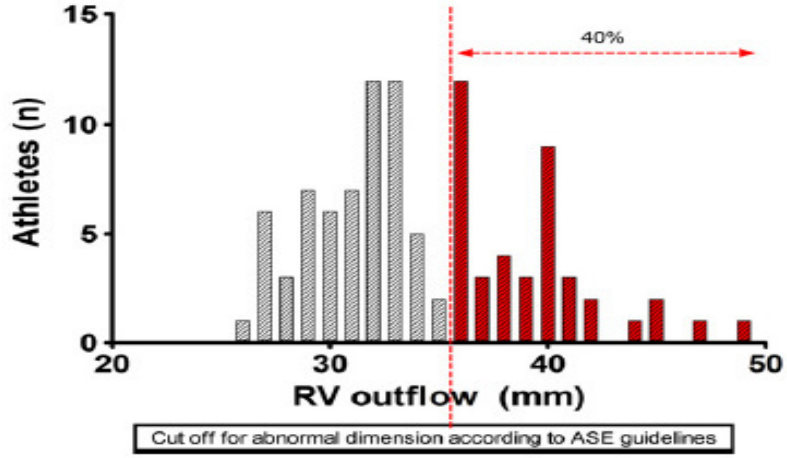

Figure 3 Range of values for RV proximal outflow dimension in endurance athletes (n = 102).

Oxborough et al. *J Am Soc Echocardiogr* 2012;25:263.

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- *Physiologic RV Chamber Enlargement:*
  - Expected with endurance training.
  - Global RV process without sacculation, aneurysmal dilation, segmental dysfunction, or fibrosis (?).
  - RV dimensions “cut-offs” are not helpful.
  - “Always” associated with LV remodeling (concomitant LV enlargement but no RVH).
  - Accompanied by normal to low normal resting FAC / RVEF.
  - TDI / Strain assessment with preserved or enhanced function.
  - If in doubt, comprehensive exercise testing and rhythm monitoring.

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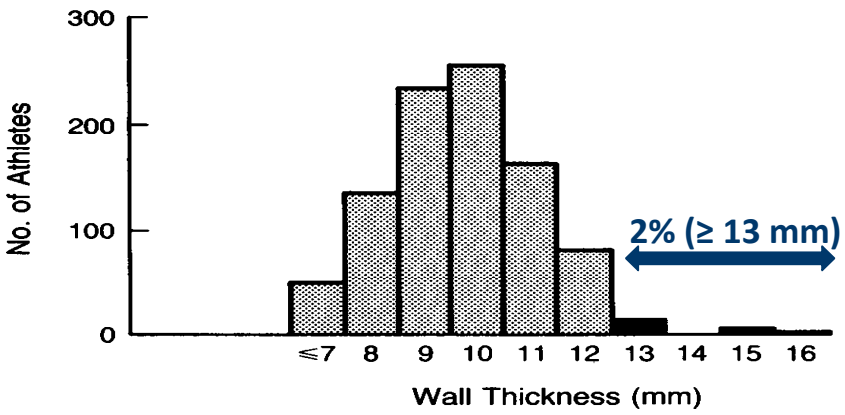
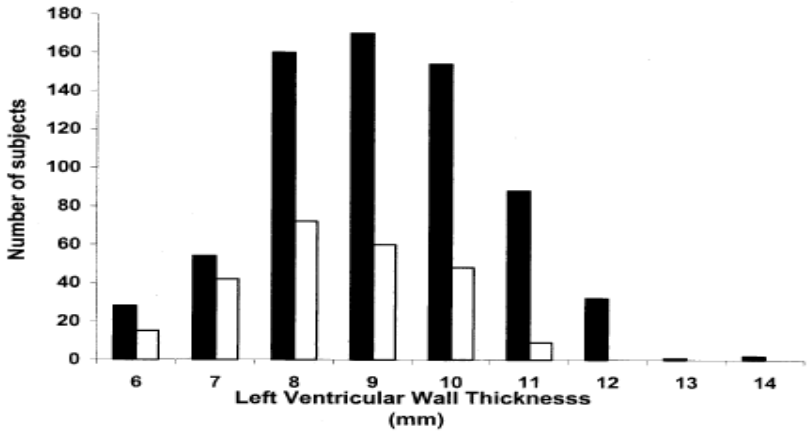
Thick LV Walls

Adult Athletes



Pelliccia et al. *N Engl J Med* 1991.

Junior Athletes



Sharma et al. *J Am Coll Cardiol* 2002.

Least frequent, but most problematic

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Thick LV Walls

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Not a single healthy college athlete with walls > 14 mm

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Weiner et al. *J Am Soc Echocardiogr* 2012;25:568.

- *Physiologic Thick LV Walls:*
  - Physiologic concentric LVH is symmetric without regional variation.
    - Marked asymmetry is pathology until proven otherwise.
  - Wall thickness "cut-offs" are VERY helpful.
  - Accurate absolute thicknesses >15 mm are pathologic until proven otherwise.
  - E' values may be helpful, but not diagnostic
  - Exercise testing (CPET) is a useful discriminator
  - Detraining may be necessary to arrive at a final diagnosis.

This is the HCM mimicker

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Other Areas of Study

- Atria
  - LA dilation: endurance > strength athletes

    Iskander et al. *JACC Cardiovasc Imaging*, 2015.

  - LA function: atrial strain and contraction
- Aorta
  - Sinus of Valsalva: 3.2 mm greater in athletes

    Iskander et al. *Circulation*, 2013.

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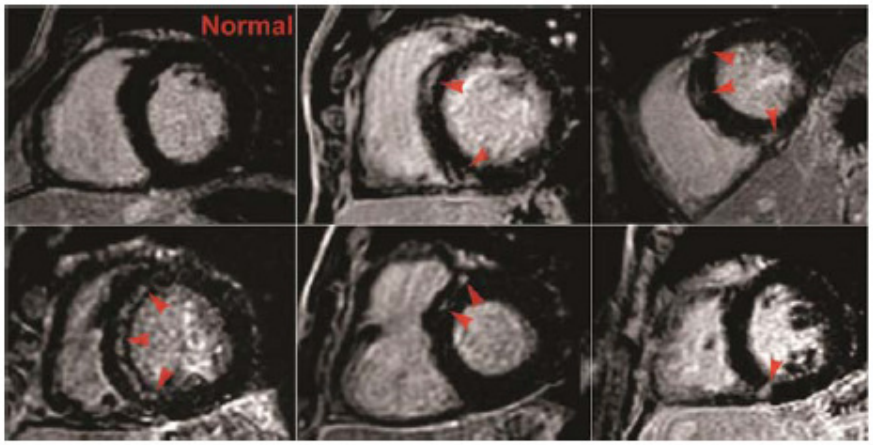
Future Directions

- Myocardial mechanics
  - LV strain, twist (regional function)
- Cardiac MRI



La Gerche et al. *Eur Heart J.* 2012; 33:998.

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Summary

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Thick LV Walls

Key Differential Diagnosis
Hypertrophic cardiomyopathy
Hypertensive heart disease
Infiltrative heart disease
Valvular heart disease

Clinical Factors c/w of Athlete's Heart
Strength training background
No subjective symptoms
Benign family history
Normal subjective exercise capacity

Echo Findings c/w Athlete's Heart
Mild symmetric LVH (walls <15 mm)
Normal RV dimensions
Normal / mildly enlarged LA
Normal aortic valve function
Normal mitral valve anatomy

Additional Diagnostic Considerations
Exercise testing (VO_2 assessment)
24h ambulatory BP monitor
Cardiac MRI
? Prescribed detraining

Dilated LV Chamber

Key Differential Diagnosis
Idiopathic dilated cardiomyopathy
Toxic (ETOH, drugs) cardiomyopathy
Infectious cardiomyopathy
Cardiomyopathy 2° tachyarrhythmia

Clinical Factors c/w of Athlete's Heart
Endurance training background
No subjective symptoms
Benign family history
No history of prior illness / substance abuse
Normal subjective exercise capacity

Echo Findings c/w Athlete's Heart
Concomitant RV dilation
Mild LV wall thickening
Supra-normal LV diastolic indices
Normal / mildly enlarged LA & RA

Additional Diagnostic Considerations
Exercise testing (VO_2 assessment)
Ambulatory rhythm monitoring
Cardiac MRI

Dilated RV Chamber

Differential Diagnosis
Arrhythmogenic RV cardiomyopathy
Idiopathic dilated cardiomyopathy
Pulmonary HTN / congenital heart disease
Sarcoidosis
Cardiomyopathy 2° tachyarrhythmia

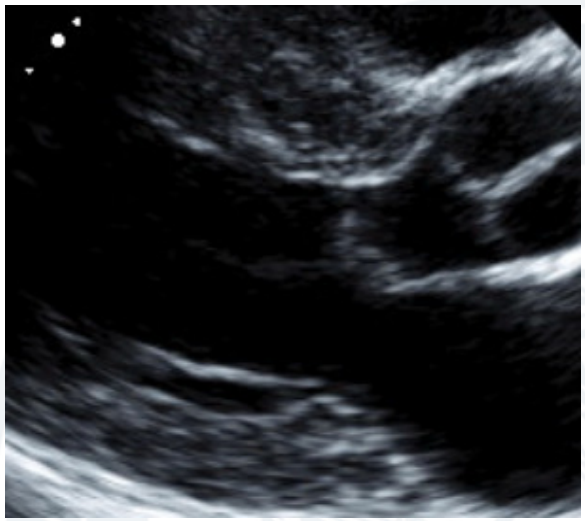
Clinical Factors c/w of Athlete's Heart
Endurance training background
No subjective symptoms
Benign family history
Normal subjective exercise capacity

Echo Findings c/w Athlete's Heart
Concomitant LV dilation
Normal RV morphology
Supra-normal LV diastolic indices
Normal / mildly enlarged LA & RA
Normal RV systolic pressure

Additional Diagnostic Considerations
Signal averaged ECG
Exercise testing (VO_2 assessment)
Ambulatory rhythm monitoring
Cardiac MRI

Question #1

- This athlete is most likely a:
  A. Olympic marathoner
  B. Tour de France cyclist
  C. NFL Lineman
  D. Olympic swimmer



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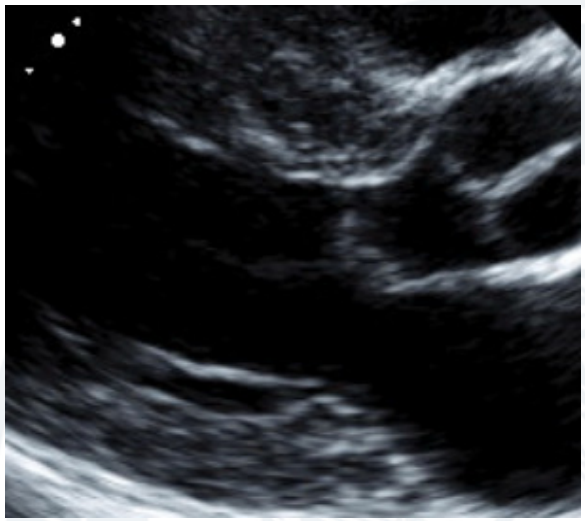

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Question #2

- Which of the following imaging findings is most likely pathologic (not Athlete's heart?)
  - A. LVIDd 59 mm in a college distance runner
  - B. RV basal diameter 47 mm in a cyclist
  - C. LA diameter 43 mm in a swimmer
  - D. LV wall thickness 16 mm in a soccer player

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