The Athletic Heart Takes Shape: Overview of Cardiac Remodeling

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Athlete’s Heart

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

1899: Initial observations by Henschen and Darling
  - Cardiac enlargement by physical exam

100+ years of scientific study:
Cardiac Remodeling

Hemodynamic Stress of Sport

Pathophysiology of Disease

MGH 1811
Cardiovascular Performance Program

American College of Cardiology
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
FIGURE Classification of Sports

I. Low (<10%)
- Bowling
- Cricket
- Curling
- Golf
- Riffley
- Yoga

II. Moderate (10-20%)
- Archery
- Auto racing
- Diving
- Equestrian
- Motorcycling

III. High (>30%)
- Bobsledding/Luge
- Field events (throwing)
- Gymnastics
- Martial arts
- Rock climbing
- Sailing
- Water skiing
- Weight lifting
- Windsurfing

A. Low (<50%)
- American football
- Field events (jumping)
- Figure skating
- Rodeoing
- Rugby
- Running (sprint)
- Surfing
- Synchronized swimming
- "Ultra" racing

B. Moderate (50-75%)
- Baseball/Softball
- Fencing
- Table tennis
- Volleyball

C. High (>75%)
- Boxing
- Canoeing
- Kayaking
- Cycling
- Decathlon
- Rowing
- Speed skating
- Triathlon

Levine et al
JACC 2015

AMERICAN COLLEGE of CARDIOLOGY
Determinants of Myocardial Adaptation

- Sporting discipline
- Gender
  - Females < males
- Ethnicity
  - Wall thickness in Afro-Caribbean descent
- Genetics / Molecular pathways
- Exercise exposure duration and “dose”
Health vs. Disease

• Can we separate athletic remodeling from pathology?

– Yes, the majority of the time when a systematic approach is used.
Evaluation “Tool Kit”

Understanding of Exercise-induced Cardiac Remodeling

Medical History & Physical Examination

12-Lead ECG

2D-Echocardiography

Advanced TTE Imaging
Cardiac MRI
Exercise Testing
Ambulatory Rhythm Monitoring
Genetic Testing
Prescribed Detraining
LV Chamber Enlargement

~40% of male athletes

LV Chamber Enlargement

25% of US college athletes exceed gender recommended LVIDd limit

Table 4 Echocardiographic findings from the study population of university athletes

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Male (n = 300)</th>
<th>Female (n = 197)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Normal (n = 209)</td>
<td>Physiologic remodeling (n = 91)</td>
</tr>
<tr>
<td>Interventricular septal thickness (mm)</td>
<td>9.8 ± 0.9</td>
<td>11.6 ± 0.5</td>
</tr>
<tr>
<td>LV posterior wall thickness (mm)</td>
<td>10.0 ± 1.2</td>
<td>11.8 ± 1.4</td>
</tr>
<tr>
<td>LV inner dimension at end-diastole (mm)</td>
<td>51 ± 3</td>
<td>67 ± 5</td>
</tr>
<tr>
<td>LA diameter (mm)</td>
<td>36 ± 4</td>
<td>40 ± 4</td>
</tr>
<tr>
<td>RV end-diastolic diameter (mm)</td>
<td>30 ± 5</td>
<td>36 ± 3</td>
</tr>
<tr>
<td>Functional parameters</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LV ejection fraction (%)</td>
<td>65 ± 7</td>
<td>58 ± 4</td>
</tr>
<tr>
<td>Transmitral E wave (cm/sec)</td>
<td>92 ± 16</td>
<td>96 ± 13</td>
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</tbody>
</table>

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

**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).
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).

• **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.
Thick LV Walls

Adult Athletes

Junior Athletes


Least frequent, but most problematic
Thick LV Walls

Not a single healthy college athlete with walls > 14 mm

• **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*
Other Areas of Study

• Atria
  – LA dilation: endurance > strength athletes
  – LA function: atrial strain and contraction

• Aorta
  – Sinus of Valsalva: 3.2 mm greater in athletes
Future Directions

• Myocardial mechanics
  – LV strain, twist (regional function)

• Cardiac MRI

Summary

**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 (wall <15 mm)
- Normal RV dimensions
- Normal / mildly enlarged LA
- Normal aortic valve function
- Normal mitral valve anatomy

**Additional Diagnostic Considerations**
- Exercise testing (VO₂ 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 (VO₂ 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 (VO₂ 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
Question #1

• This athlete is most likely a:
  A. Olympic marathoner
  B. Tour de France cyclist
  C. NFL Lineman
  D. Olympic swimmer
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
Question #2

• Which of the following imaging findings is most likely pathologic (not Athlete’s heart?)
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