Echo Evaluation of the Heart of an Athlete

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Mayo Clinic, Rochester
Echo Evaluation of the Heart of an Athlete

• A growing number of adults engages in sports

• Sports participation
  • plays a role in promoting healthy living, emotional and cognitive development
  • does not confer complete immunity against heart disease
  • can increase the risk of CV events even in trained individuals
18 YO professional hockey scouting

Cardiomyopathy or physiologic adaptation to Exercise? What is risk of SD if he plays hockey?
SD is rare among young athletes but it is always a tragedy.

Exaggerated media coverage give the impression that this tragedy are far more common than they actually are and are limited to athletes.
Echo Evaluation of the Heart of an Athlete

1. Define the scope of the SD in athletes
2. Identify causes of SD in athletes
3. Define the role of Echo in identifying patients at risk without known heart disease
   - Differentiating pathology from physiologic response of CV system to different forms of Exercise
Competitive Athletes: Risk of SCD Estimates

- High school: 30% or 4 M, 1/65,000
- College: 1% or 500K, 1/50,000
- Pro: 5000

SCD occurs in 1/80,000 to 1/40,000 in all athletes. In the US, more in male of Afro-Caribbean descent.
# Causes of Sudden Death in 387 Young Athletes

<table>
<thead>
<tr>
<th>Cause</th>
<th>No.</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hypertrophic cardiomyopathy</td>
<td>102</td>
<td>26.4</td>
</tr>
<tr>
<td>Commotio cordis</td>
<td>77</td>
<td>19.9</td>
</tr>
<tr>
<td>Coronary artery anomalies</td>
<td>53</td>
<td>13.7</td>
</tr>
<tr>
<td>LVH of indeterminate cause</td>
<td>29</td>
<td>7.5</td>
</tr>
<tr>
<td>Myocarditis</td>
<td>20</td>
<td>5.2</td>
</tr>
<tr>
<td>Ruptured Ao aneurysm (MFS)</td>
<td>12</td>
<td>3.1</td>
</tr>
<tr>
<td>Arrhythmogenic RV cardiomyopathy</td>
<td>11</td>
<td>2.8</td>
</tr>
<tr>
<td>Tunneled (bridged) coronary artery</td>
<td>11</td>
<td>2.8</td>
</tr>
<tr>
<td>Ao valve stenosis</td>
<td>10</td>
<td>2.6</td>
</tr>
<tr>
<td>Atherosclerotic CAD</td>
<td>10</td>
<td>2.6</td>
</tr>
</tbody>
</table>

Maron and Zipes: JACC 45:1318, 2005
Distribution by Age of Sports-related Sudden Death

Sport related Sudden Death occurs in all ages and not only competitive athletes

Eloi Marijon et al. Circulation. 2011
Pathology of SD during recreational sports

- Spain 1995-2010
- 168 / 8862 SDs (1.8%)
  - cycling (29.1%)
  - soccer (25.5%)
- Mean age was 36.6 ± 15.6 yrs.
  - 81 (48.2%) were ≤ 35 YO
  - 87 (51.7%) were > 35 YO

<table>
<thead>
<tr>
<th></th>
<th>CAD</th>
<th>ACM</th>
<th>HC M</th>
<th>ILVH</th>
<th>CCA</th>
<th>MYO</th>
<th>AoS</th>
<th>No Cause</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>168 (100%)</td>
<td>85 (50.5%)</td>
<td>13 (7.7%)</td>
<td>12 (7.1%)</td>
<td>7 (4.1%)</td>
<td>7 (4.1%)</td>
<td>6 (3.5%)</td>
<td>5 (2.9%)</td>
</tr>
<tr>
<td>9–35 (22.8 ± 7)</td>
<td>81 (48.2%)</td>
<td>11 (13.5%)</td>
<td>12 (14.8%)</td>
<td>8 (9.8%)</td>
<td>7 (8.6%)</td>
<td>5 (6.1%)</td>
<td>4 (4.9%)</td>
<td>3 (3.7%)</td>
</tr>
<tr>
<td>36–79 (49.4 ± 9)</td>
<td>87 (51.7%)</td>
<td>74 (85%)</td>
<td>1 (1.1%)</td>
<td>4 (4.5%)</td>
<td>0</td>
<td>2 (2.2%)</td>
<td>2 (2.2%)</td>
<td>2 (2.2%)</td>
</tr>
</tbody>
</table>
Echo screening for Heart Disease associated with Sudden Death

Age <35 yrs.
- HCM
- Coronary anomalies
- LVH of indeterminate cause
- Myocarditis/sarcoid/DCMP/Alc.
- Aortic aneurysm (MFS)
- Arrhythmogenic RVD
- AV stenosis/ Myxomatous MV
- Coronary disease

Age ≥ 35 yrs.
- Coronary disease
- Aortic stenosis
- Myxomatous MV
- HCM
- Coronary anomalies
ALCAPA
Anomalous LCA from PA
Echo Evaluation of the Heart of an Athlete

• Accurate interpretation of diagnostic testing with an emphasis on
  • Identifying structural causes of SCD
  • Targeted assessment of symptoms in athletes
    • Cardio-pulmonary Vo2 Stress Echo
    • Differentiating pathology from physiological exercise-induced adaptation
Classification of Sports

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

A. Low (<50%)
- Archery
- Auto racing†
- Diving†
- Equestrian†
- Motorcycling†

II. Moderate (10-20%)
- Bobsledding/Luge
- Field events (throwing)
- Gymnastics†
- Martial arts
- Rock climbing
- Sailing
- Water skiing†
- Weight lifting†
- Windsurfing†

B. Moderate (50-75%)
- Body building†
- Downhill skiing
- Skateboarding†
- Snowboarding†
- Wrestling*

III. High (>30%)
- Boxing
- Canoeing
- Kayaking
- Cycling†
- Decathlon
- Rowing
- Speed skating
- Triathlon†

C. High (>75%)
- American football*
- Field events (jumping)
- Figure skating
- Rodeoeing†
- Rugby
- Running (sprint)
- Surfing
- Synchronized swimming†
  “Ultra” racing

- Basketball*
- Ice hockey*
- Cross-country skiing
  (skating technique)
- Lacrosse*
- Running (middle distance)
- Swimming
- Team handball
- Tennis

- Badminton
- Cross-country skiing
  (classic technique)
- Field hockey*
- Orienteering
- Race walking
- Racquetball/Squash
- Running (long distance)
- Soccer*
Exercise-induced CV Remodeling or Pathology

- CV system adapts to repetitive bouts of exercise through a complex series of structural and functional changes.

- **Static activity**: short and forceful skeletal muscle contractions
  - Acute ↑ in SVR and BP: ↑ in afterload
  - CV response: increased myocardial contractility to maintain CO leading to LVH without dilatation.

- **Dynamic/endurance activity**: repetitive, rhythmic skeletal muscle contraction-relaxation requiring more O2 uptake
  - CV response is to ↑ CO: ↑ in HR and SV, with ↓ in SVR
  - Eccentric hypertrophy with 4C dilatation and aortic root dilatation.
Classification of Sports

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

A. Low (<50%)
- Baseball/Softball
- Fencing
- Table Tennis
- Volleyball

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

B. Moderate (50-75%)
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- Rowing
- Speed skating
- Triathlon

Levine: Circulation, 2015
Exercise-induced CV Remodeling or Pathology

Most sports: static + dynamic stress elements

- Rowing
- Canoeing
- Kayaking
- Cycling
- Decathlon
- Speed skating
- Triathlon

Baggish et al. JACC. 70, NO. 15, 2017
Exercise-induced CV Remodeling or Pathology

- CV remodeling varies across athletic populations and individual athletes
  - epigenetic factors including
    - sporting discipline
    - duration of exercise exposure
  - ethnicity
  - gender
  - genetics (underlying genome)
# Impact of training type on Echo parameters

<table>
<thead>
<tr>
<th></th>
<th>Endurance</th>
<th>Resistance</th>
<th>Sedentary</th>
<th>P-value</th>
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</thead>
<tbody>
<tr>
<td>LV mass (g)</td>
<td>232 (200-260)</td>
<td>220 (205-234)</td>
<td>166 (145-186)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td></td>
<td>[n=64; 1099]</td>
<td>[n=25; 510]</td>
<td>[n=59; 1239]</td>
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<tr>
<td>IVSd (mm)</td>
<td>11.0 (10.8-11.3)</td>
<td>11.0 (10.3-11.8)</td>
<td>9.2 (8.9-9.5)</td>
<td>&lt;0.001</td>
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<tr>
<td></td>
<td>[n=68; 1802]</td>
<td>[n=19; 408]</td>
<td>[n=63; 1352]</td>
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<tr>
<td>LVPWd (mm)</td>
<td>10.6 (10.3-10.9)</td>
<td>10.4 (9.8-10.9)</td>
<td>8.8 (8.6-9.1)</td>
<td>&lt;0.001</td>
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<tr>
<td></td>
<td>[n=57; 1928]</td>
<td>[n=14; 370]</td>
<td>[n=53; 1433]</td>
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<tr>
<td>LVDd (mm)</td>
<td>54.8 (54.1-55.6)</td>
<td>52.4 (51.2-53.6)</td>
<td>50.1 (49.5-50.7)</td>
<td>&lt;0.001</td>
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<tr>
<td></td>
<td>[n=61; 1548]</td>
<td>[n=17; 384]</td>
<td>[n=56; 1174]</td>
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<tr>
<td>LVEDV (ml)</td>
<td>171 (157-185)</td>
<td>131 (120-142)</td>
<td>135 (125-145)</td>
<td>&lt;0.001</td>
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<tr>
<td></td>
<td>[n=34; 493]</td>
<td>[n=14; 189]</td>
<td>[n=34; 539]</td>
<td></td>
</tr>
<tr>
<td>LV SV (ml)</td>
<td>106 (97-116)</td>
<td>86 (77-95)</td>
<td>83 (77-90)</td>
<td>&lt;0.001</td>
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<tr>
<td></td>
<td>[n=28; 479]</td>
<td>[n=9; 125]</td>
<td>[n=27; 590]</td>
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<tr>
<td>LV EF (%)</td>
<td>63 (61-64)</td>
<td>66 (62-70)</td>
<td>64 (62-65)</td>
<td>0.365</td>
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<tr>
<td></td>
<td>[n=42; 1330]</td>
<td>[n=7; 85]</td>
<td>[n=37; 878]</td>
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</tr>
<tr>
<td>LV E/A</td>
<td>2.0 (1.9-2.1)</td>
<td>1.9 (1.7-2.0)</td>
<td>1.8 (1.7-1.9)</td>
<td>0.014</td>
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<tr>
<td></td>
<td>[n=34; 844]</td>
<td>[n=8; 214]</td>
<td>[n=34; 868]</td>
<td></td>
</tr>
<tr>
<td>LV e'</td>
<td>13.6 (12.3-14.9)</td>
<td>*</td>
<td>11.0 (9.4-12.6)</td>
<td>0.014</td>
</tr>
<tr>
<td></td>
<td>[n=7; 204]</td>
<td></td>
<td>[n=4; 183]</td>
<td></td>
</tr>
<tr>
<td>RV mass (g)</td>
<td>91 (63-119)</td>
<td>*</td>
<td>37 (24-50)</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td></td>
<td>[n=5; 116]</td>
<td></td>
<td>[n=4; 102]</td>
<td></td>
</tr>
<tr>
<td>RVD1 (mm)</td>
<td>33.5 (21.0-46.0)</td>
<td>*</td>
<td>26.1 (16.1-36.1)</td>
<td>0.347</td>
</tr>
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<td></td>
<td>[n=4; 140]</td>
<td></td>
<td>[n=4; 95]</td>
<td></td>
</tr>
<tr>
<td>RVEDV (ml)</td>
<td>222 (216-227)</td>
<td>*</td>
<td>156 (153-159)</td>
<td>0.627</td>
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<tr>
<td></td>
<td>[n=6; 136]</td>
<td></td>
<td>[n=6; 150]</td>
<td></td>
</tr>
<tr>
<td>RV SV (ml)</td>
<td>114 (115-122)</td>
<td>*</td>
<td>94 (92-98)</td>
<td>0.415</td>
</tr>
<tr>
<td></td>
<td>[n=5; 66]</td>
<td></td>
<td>[n=4; 66]</td>
<td></td>
</tr>
<tr>
<td>LA Size (mm)</td>
<td>39.2 (35.9-42.5)</td>
<td>31.9 (29.7-34.1)</td>
<td>34.9 (31.9-37.9)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td></td>
<td>[n=10; 206]</td>
<td>[n=2; 58]</td>
<td>[n=11; 243]</td>
<td></td>
</tr>
</tbody>
</table>

* indicates statistical significance.
Athlete’s Heart
Role of Echocardiography

- **Gender**: Ch. dimensions in ♀ athletes rarely abnormal
  - Eccentric remodeling of all cardiac chambers in ♂

- **AGE**: Junior athletes cardiac remodeling is often at a lower magnitude than in senior athletes

- **RACE**: LV/ RV volume changes similar in Black / white athletes
  - WT/ LA size are often larger in Black athletes
  - Any WT > 12mm in white ♂ ♀ or > 14mm in Black ♂ and any WT>13 mm in Black ♀ athletes deserves investigation

- **BSA**: all chamber dimensions should be indexed for BSA
  - If extremes of height and weight (BSA > 2.3m2)
    - non-indexed WT should not exceed 14 mm
    - non-indexed LVEDD should not exceed 65mm
Gray Zone: *Overlap Between Adaptation and Pathology particularly in male*

- 14% exhibit a LV cavity size resembling DCMP
- 12% of endurance athletes show reduced EF
- 37% of male athletes have a RVE that fulfils a criterion in the revised “task force criteria” for diagnosing ARVC
- 8% of athletes fulfilling echo criteria for isolated left ventricular non-compaction
- 13% to 18% of black male athletes have a LVWT compatible with morphologically mild HCM

**Essential skills needed to differentiate Exercise-induced CV Remodeling from CV Pathology**

*Sharma; JAMA Internal Medicine, 2015*
Echo Criteria to Distinguish HCM from Athlete’s Heart

“Grey zone” of LV wall thickness (13-15 mm)

- **HCM**
  - High RWT
  - Normal Ao root
  - \( \downarrow \downarrow \) DTI MV E’ <11.5
  - \( \downarrow \downarrow \) long. strain
  - Unusual patterns of LVH
  - LV cavity <45 mm
  - LV cavity >55 mm
  - Marked LA enlargement
  - Bizarre ECG patterns
  - Abnormal LV filling
  - Female sex
  - \( \downarrow \) thickness with deconditioning
  - Family history of HCM
  - Max VO\(_2\) >45 mL/kg/min
  - >110% predicted

- **Athlete’s heart**
  - Low RWT
  - Larger Ao root
  - \( \uparrow \uparrow \) DTI MV E’
  - NL or\( \uparrow \) strain

Modified from Maron Heart 91:2005
Pathological vs. Physiological Adaptation
Role of Echocardiography

Consider Physiologic

Correlate with clinical data (ECG, symptoms, demographics, FH)

No evidence of dyskinesis, akinesis or aneurysm

RVOT1 > 35mm or > 21mm/m² OR
RVD1 > 42mm OR
RV:LV ratio > 0.66

Assess RV systolic Function

TAPSE

>16 mm

<16 mm

> 33 %

< 33 %

Right Ventricular Fractional Area Change

Right Ventricular PW TDI of the tricuspid annulus

S’ > 10 cm/s

S’ < 10 cm/s

Subjective Assessment

Consider Pathology

Correlate with clinical data

Refer to BSE algorithms

Evidence of dyskinesis, akinesis or aneurysm

Pathological Adaptation More Likely

Physiological Adaptation More Likely
Clinical Differentiation Between Physiological Remodeling and Arrhythmogenic Right Ventricular Cardiomyopathy in Athletes With Marked Electrocardiographic Repolarization Anomalies

Abbas Zaidi, BSc (Hons), MBBS, MD,* Nabeel Sheikh, BSc (Hons), MBBS,* Jesse K. Jongman, MD,† Sabiha Gati, BSc (Hons), MBBS,* Vasileios F. Panoulas, MD, PhD,‡ Gerald Carr-White, BSc (Hons), MBBS, PhD,§ Michael Papadakis, MBBS, MD,* Rajan Sharma, BSc (Hons), MBBS, MD,* Elijah R. Behr, MBBS, MD,* Sanjay Sharma, BSc (Hons), MBCchB, MD*
18 YO professional hockey scouting

Primary CMP or physiologic adaptation of CV system?
Initial CMR

LGE

patchy LGE
18 yo, f/u after 1 year of de-training
18 yo, f/u after 1 year of de-training

1. Physiologic myocardial atrophy occurs at ~1%/week
2. Detraining not been regularly tested: time course uncertain
3. No data defining effect of exercise abstinence in CMP
Athlete’s Heart
Role of Echocardiography

- Screening for HD associated with sudden death
- Extent and nature of physiological cardiac adaptation in the athlete’s heart in relation to
  Age, gender, ethnicity, BSA, sports type-duration
- Prior knowledge of these demographics + ECG + FHx
  Aid interpretation of findings
  Contribute to subsequent management
- Despite improved diagnostic yield from Echo in differentiating pathology from physiologic adaptation,
  some challenges do exist especially in the “gray zone”