Preventing Sudden Cardiac Arrest in Athletes

Christina L. Master, MD, FAAP, CAQSM, FACSM, FAMSSM
Professor of Pediatrics and Orthopaedic Surgery
University of Pennsylvania Perelman School of Medicine
Co-Director, Minds Matter Concussion Program
Sports Medicine and Performance Program
Children's Hospital of Philadelphia

34th Annual Ironman World Championship Medical Symposium
20 October 2024
Kailua-Kona, Hawai'i

Children's Hospital of Philadelphia
Division of Orthopaedics

Perelman School of Medicine
University of Pennsylvania

IRONMAN WORLD CHAMPIONSHIP MEDICAL SYMPOSIUM
October 20-24,2024
Outrigger Kona Resort, Kailua-Kona Hawai'i

I have no financial relationships to disclose or Conflicts of Interest to resolve.

I have received research is funding from the NIH, CDC, NCAA, DOD, PA Department of Health, AMSSM Foundation, CHOP Frontier Programs, Toyota Way Forward Fund

IRONMAN WORLD CHAMPIONSHIP MEDICAL SYMPOSIUM
October 20-24,2024
Outrigger Kona Resort, Kailua-Kona Hawai'i

Children's Hospital of Philadelphia
Division of Orthopaedics

Perelman School of Medicine
University of Pennsylvania

Objectives

- Understand principles of sports injury prevention generally
- Recognize extent of the issue of sudden cardiac arrest in sports
- Describe strategies for primary and secondary prevention in sudden cardiac arrest
- Discuss issues relating to mass pre-participation screening
- Implement cardiac arrest emergency action plans

IRONMAN WORLD CHAMPIONSHIP MEDICAL SYMPOSIUM
October 20-24,2024
Outrigger Kona Resort, Kailua-Kona Hawai'i

Children's Hospital of Philadelphia
Division of Orthopaedics

Perelman School of Medicine
University of Pennsylvania

How to save a life

IRONMAN
WORLD CHAMPIONSHIP
MEDICAL SYMPOSIUM
October 20-24,2024
Outrigger Kona Resort, Kailua-Kona Hawai'i

Children's Hospital of Philadelphia
Division of Orthopaedics

Perelman School of Medicine
University of Pennsylvania

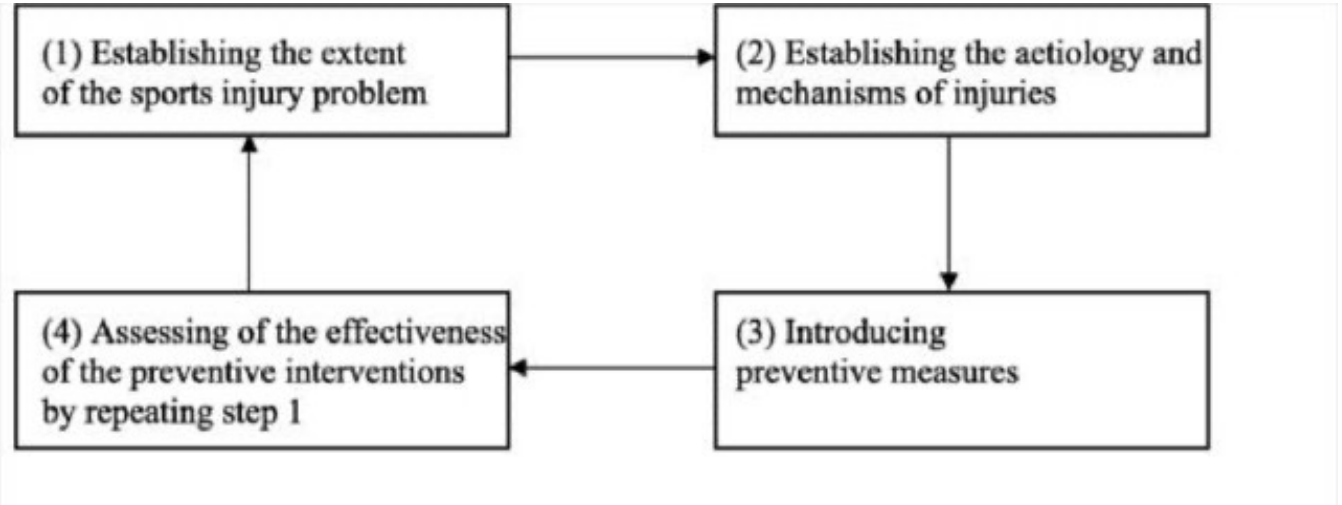
What would you do?

- 14 yo ice hockey player, otherwise healthy
- No personal cardiac history
- Here for sports physical
- What would you do for pre-participation evaluation?

Children's Hospital of Philadelphia
Division of Orthopaedics

Perelman School of Medicine
University of Pennsylvania

Prevention Framework



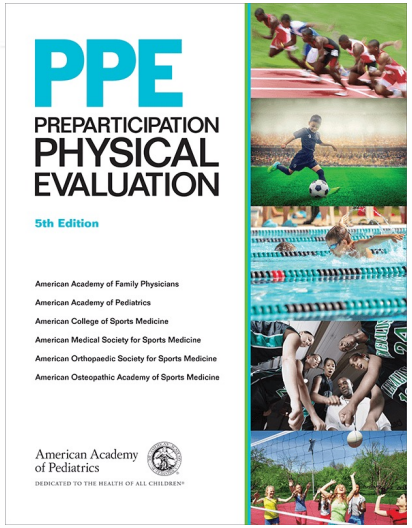
IRONMAN WORLD CHAMPIONSHIP MEDICAL SYMPOSIUM
October 20-24,2024
Outrigger Kona Resort, Kailua-Kona Hawai'i

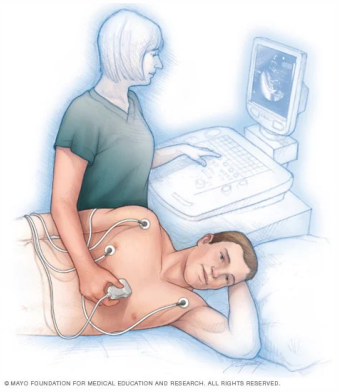
Children's Hospital of Philadelphia Division of Orthopaedics
Perelman School of Medicine University of Pennsylvania

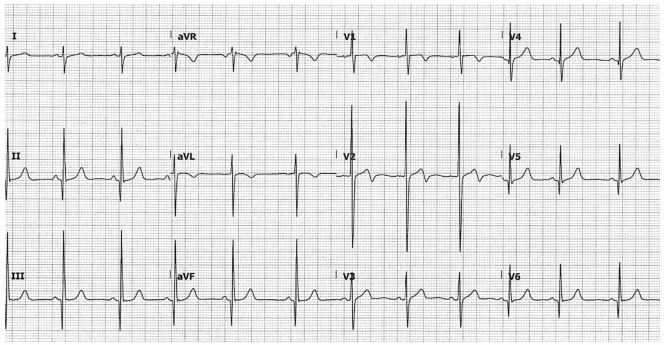
van Mechelen W, *Sports Med*, 1992

Levels of Prevention

- Primary prevention - preventing the problem before it happens (sudden cardiac arrest/SCA)
  - Possible approaches include preventing hazards that cause injury, change behavior, enact legislation, provide education
  - For SCA – potential strategies include widespread cardiac screening (EKG, exercise testing), genetic testing







IRONMAN WORLD CHAMPIONSHIP MEDICAL SYMPOSIUM
October 20-24,2024
Outrigger Kona Resort, Kailua-Kona Hawai'i

Children's Hospital of Philadelphia
Division of Orthopaedics

Perelman School of Medicine
University of Pennsylvania

Levels of Prevention

- Secondary prevention - preventing the negative effects (morbidity/death) after an event (cardiac arrest)
  - Possible approaches include reducing impact of injury that has occurred, early treatment, return to original state of health and prevent recurrence
  - For SCA - widespread deployment of AEDs, training personnel and the public on CPR and AED use

IRONMAN WORLD CHAMPIONSHIP MEDICAL SYMPOSIUM
October 20-24,2024
Outrigger Kona Resort, Kailua-Kona Hawai'i

Children's Hospital of Philadelphia
Division of Orthopaedics

Perelman School of Medicine
University of Pennsylvania

Preventing Sudden Cardiac ~~Arrest~~ Death

- Scope of the problem
- Etiology/Causes
- Primary prevention interventions
  - Pre-participation physical
  - Electrocardiogram (ECG)
  - Additional testing
- Secondary prevention interventions
  - Cardio-pulmonary Resuscitation (CPR)
  - Automated External Defibrillator (AED)
- Other considerations

Children's Hospital of Philadelphia
Division of Orthopaedics
Perelman School of Medicine
University of Pennsylvania

How big is the problem?

- Age-dependent in competitive athletes
  - ≤35 yo - 0.47-1.21 per 10,000 person years
  - ≥35 - 6.64 per 10,000 person years
- NCAA
  - SCD 1:43,770, 17-23 yo
  - But SCD 1:17,696 per year in black and 1:5284 per year DI African-American college basketball
- Young African-American athletes - 3x greater risk than white athletes - 5.6/1000,000 per year
- National Center for Catastrophic Injury Research
  - AA male NCAA DI basketball1:2087 athlete years
- Corrado et al. M>F - 2.6/100,000 person years vs. 1.1/100,000

NCAA®

NCCSIR
National Center for Catastrophic Sport Injury Research

IRONMAN WORLD CHAMPIONSHIP MEDICAL SYMPOSIUM
October 20-24,2024
Outrigger Kona Resort, Kailua-Kona Hawai'i

Children's Hospital of Philadelphia
Division of Orthopaedics

Perelman School of Medicine
University of Pennsylvania

Epidemiology of sudden cardiac arrest

- Sports-related SCA in a prospective registry of 3,775 from 2002-2015, Portland, OR
  - 39% of SCA among those <18 yo
  - 13% for those 19-25
  - 7% ages 25-34
- Sports and Fitness Industry Association from 2007-2015
  - 1.83 deaths per 10 million athlete-years
- Preparticipation screening of 5,169 middle and high school students, 2010-2017, mean age 13 years
  - Revealed high risk cardiovascular conditions in 1.47%
- Rates increase with age, 0.75 per 100,000 athlete years, may be first manifestation but 29% may have had svmptoms before

SFIA
Sports & Fitness Industry Association

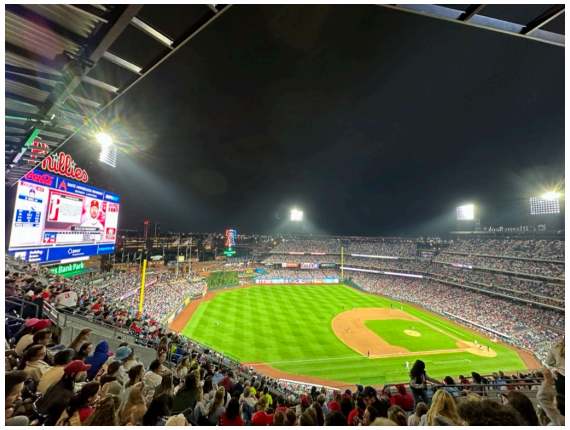
IRONMAN
WORLD CHAMPIONSHIP
MEDICAL SYMPOSIUM
October 20-24,2024
Outrigger Kona Resort, Kailua-Kona Hawai'i

Children's Hospital of Philadelphia
Division of Orthopaedics
Perelman School of Medicine
University of Pennsylvania

AHA Heart and Stroke statistics – 2022 update

Role of exercise

- Association of SCA/SCD with strenuous exercise
  - Greater risk in competitive athletes than recreational exercise - 1:100,000 vs 0.32/100,000
- SCA RR 3.6 in HS student athletes vs. sedentary athletes – but some conflicting data
- Most common sports in US - basketball, American football and soccer
- In Europe – 40-45% of all SCD events occur in football



IRONMAN WORLD CHAMPIONSHIP MEDICAL SYMPOSIUM
October 20-24,2024
Outrigger Kona Resort, Kailua-Kona Hawai'i

Children's Hospital of Philadelphia
Division of Orthopaedics

Perelman School of Medicine
University of Pennsylvania

What are the causes?

- >35 yo - atherosclerotic coronary artery disease predominates
  - Idiopathic LVH with idiopathic fibrosis - unclear relationship but appears to be different from HCM
  - HCM, ARVD/C, electrical disease, myocarditis
- ≤35 cardiomyopathies, channelopathies, congenital
  - US: HCM highest 36% of all SCD in young athletes
    - HCM is less common in Italy where ARVD/C was most common 23% with HCM only 2%
  - US DoD: 41% normal heart, 13% HCM
    - Older 73% atherosclerosis
  - NCAA: 25% normal heart, 11% coronary artery anomaly, 8% HCM
  - Acquired: commotio cordis, myocarditis, performance-enhancing drugs, Kawasaki syndrome
  - Sudden arrhythmic death syndrome
    - SCD with structurally normal heart - probably a primary arrhythmia – long QT, Brugada, catecholaminergic polymorphic tachycardia, or arrhythmogenic phenotype before structural phenotype expressed
    - Genetic testing or molecular autopsy may be helpful

The bottom line

ORCCA

0.3%
prevalence of heart conditions associated with SCA

65%
of SCA occurs in basketball, American football and soccer

1 in 2,000
incidence of SCA in Black, male, Division I basketball players

Over 10
college athletes per year with SCA

IRONMAN WORLD CHAMPIONSHIP MEDICAL SYMPOSIUM
October 20-24,2024
Outrigger Kona Resort, Kailua-Kona Hawai'i

Children's Hospital of Philadelphia
Division of Orthopaedics

Perelman School of Medicine
University of Pennsylvania

Disparities in SCA in athletes

Figure 2. Principles for Eliminating Racial Disparities in Sports Cardiology

Race-conscious awareness

- If proven a normal ECG finding, athletic anterior repolarization should be generalized to all athletes, irrespective of race
- Eliminate race as a clinical diagnostic/therapeutic variable in clinical algorithms
- When encountering concentric LVH, assess environmental influences like hypertension, considering factors beyond race

Clinical inclusivity

- Diversify the sports medicine and sports cardiology workforce and other health teams in sports medicine
- Include diverse groups in research studies, as these lay the foundation for generalizable clinical algorithms
- A proven lifesaving device, ensure AED access in all athletic arenas, especially in underserved communities

Research-driven practice refinement

- Allocate more federal and foundation funding to explore racial disparities in athlete cardiac outcomes
- Broaden studies on cardiac phenotypic variation to understand healthy variation
- Avoid pathologizing groups. Instead, define and study the full spectrum of human variation

Children's Hospital of Philadelphia
Division of Orthopaedics

Perelman School of Medicine
University of Pennsylvania

What can we do? Primary Prevention with Pre-Participation Screening

- Personal Medical History
  - Exertional chest pain/discomfort
  - Unexplained syncope/near syncope
  - Excessive exertional and unexplained dyspnea/fatigue, associated with exercise
  - Previous recognition of a heart murmur
  - Elevated systemic blood pressure
  - Previous restriction from participation in sports
  - Previous testing for the heart, ordered by a physician
- Family
  - Premature death (sudden/unexplained otherwise) <50 yo due to heart disease, in ≥1 relative
  - Disability from heart disease in a close relative < 50 yo
  - Specific knowledge of certain cardiac conditions in family members: HCM/DCM, long QT, or other ion channelopathies, Marfan Syndrome or clinically important arrhythmias
- Physical examination
  - Heart murmur – auscultation supine, standing, Valsalva, femoral pulses, brachial BP seated, Marfan stigmata

American Heart Association.

AMERICAN COLLEGE of CARDIOLOGY®

Children's Hospital of Philadelphia
Division of Orthopaedics

Perelman School of Medicine
University of Pennsylvania

Back to our hockey player . . .

- What would you do for pre-participation evaluation?
- Does it change if they tell you his father has HCM?
- Does it change if he tells you had a run of a fast heart rate last week that lasted a few minutes?

Children's Hospital of Philadelphia
Division of Orthopaedics

Perelman School of Medicine
University of Pennsylvania

Role of ECG in prevention

- ECG currently not recommended by AHA/ACC for universal clinical use in pre-participation evaluation of youth athletes in US
- In contrast, IOC (2004)and ESC (2005) recommend universal ECG screening for young athletes

American Heart Association.

AMERICAN COLLEGE of CARDIOLOGY®

INTERNATIONAL OLYMPIC COMMITTEE

ESC European Society of Cardiology

Children's Hospital of Philadelphia® Division of Orthopaedics

Perelman School of Medicine University of Pennsylvania

ECG screening: What are the issues?

- Bayesian pre-test prior probability
- False positives - 2-4% rate of abnormality requiring further testing vs. rate of clinically significant abnormality ~0.3% of athletes
- False negatives - in young patients, ECG only shows abnormalities in 25% teens with ARVD, 50-75% HCM
- Population differences
  - 89% decrease in SCD with ECG in Veneto region of Italy after mandatory universal screening 1982 – mostly genetic ARVD/C
  - In contrast - Israel instituted universal ECG and exercise stress testing mandate in 1997 for athletes and military and saw no decrease in SCD – likely a more heterogeneous population

ESC
European Society of Cardiology

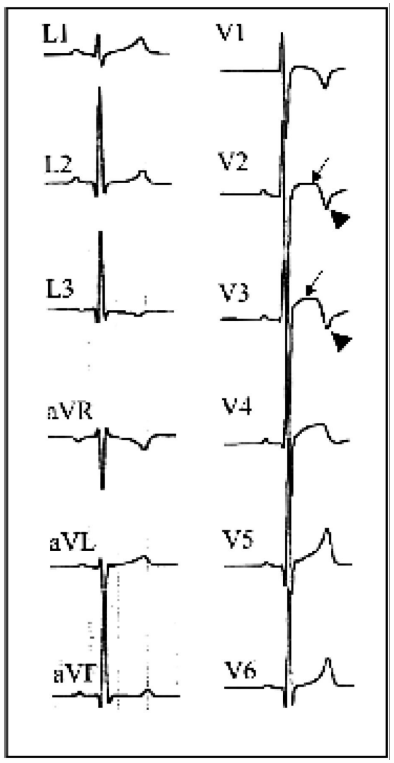
IRONMAN WORLD CHAMPIONSHIP MEDICAL SYMPOSIUM
October 20-24,2024
Outrigger Kona Resort, Kailua-Kona Hawai'i

Children's Hospital of Philadelphia
Division of Orthopaedics

Perelman School of Medicine
University of Pennsylvania

Athlete heart vs. cardiac conditions HCM

- Athlete heart demonstrates electrical structural functional physiological changes that overlap with pathology
  - Increased chamber size, myocardial wall thickness
  - Sinus brady or arrhythmia, Mobitz type I AV block, voltage criteria ventricular hypertrophy, incomplete RBBB, T wave inversion, J-point elevation with ascending ST segments
  - Increased diastolic filling and stroke volume
  - Males – more concentric remodeling hypertrophy LV
  - Females eccentric LV hypertrophy



Standardised criteria for ECG interpretation in athletes

- https://bjsm.bmj.com/pages/bjsm-education

F-MARC FOOTBALL FOR HEALTH FIFA

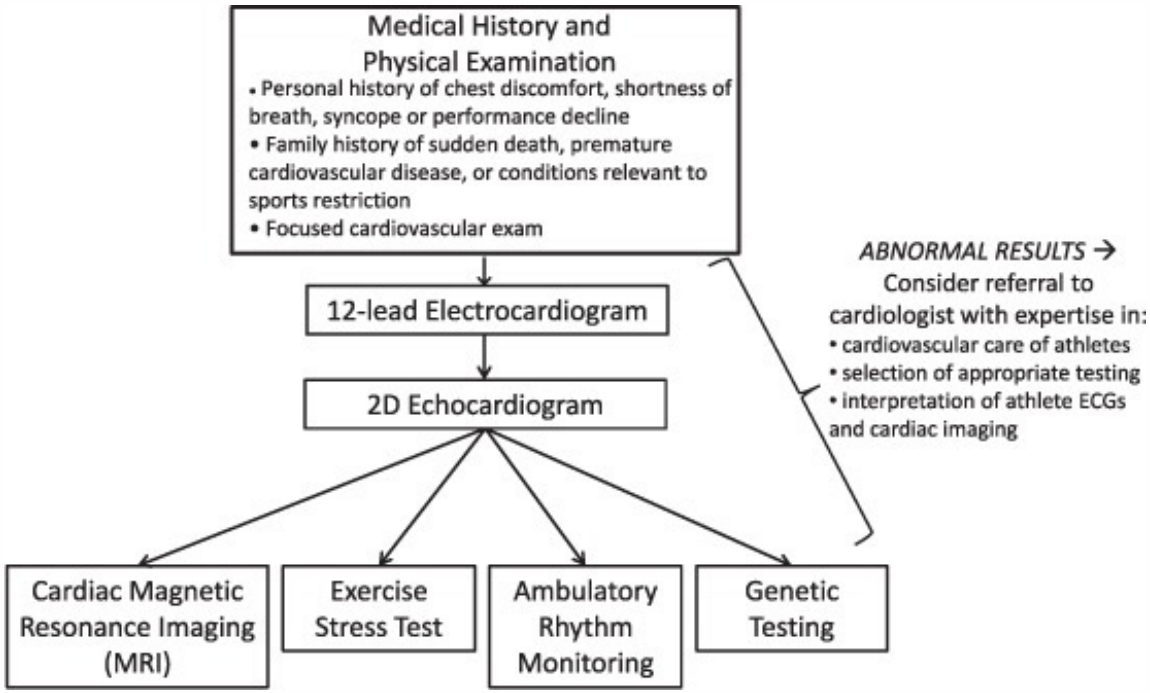
American Medical Society for Sports Medicine
Leading Sports Medicine into the Future

EACPR
European Association for Cardiovascular Prevention and Rehabilitation
A Registered Branch of the ESC

Children's Hospital of Philadelphia
Division of Orthopaedics

Perelman School of Medicine
University of Pennsylvania

Policies and clinical best practices



American Heart Association®

AMERICAN COLLEGE of CARDIOLOGY®

IRONMAN WORLD CHAMPIONSHIP MEDICAL SYMPOSIUM
October 20-24,2024
Outrigger Kona Resort, Kailua-Kona Hawai'i

Children's Hospital of Philadelphia
Division of Orthopaedics

Perelman School of Medicine
University of Pennsylvania

Results for our hockey player

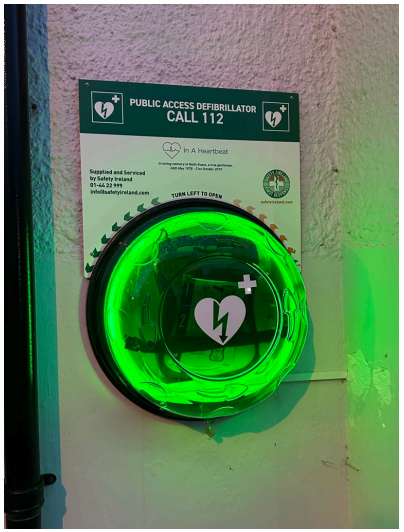
- EKG is borderline criteria for LVH
- Echo also top normal thickness interventricular septum
- Exercise stress test is normal
- Do you let him play?

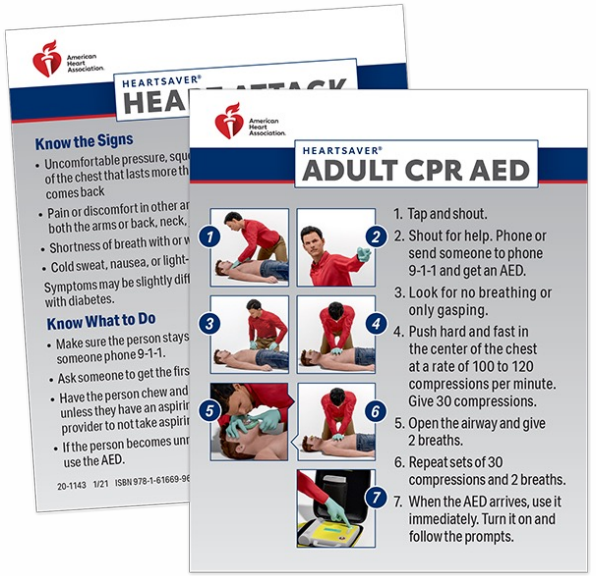
Children's Hospital of Philadelphia
Division of Orthopaedics

Perelman School of Medicine
University of Pennsylvania

What else can we do? Secondary Prevention after SCA

- Cardiopulmonary Resuscitation
  - Quality bystander CPR results in 50% survival vs. no CPR
- Automated External Defibrillators





Children's Hospital of Philadelphia
Division of Orthopaedics

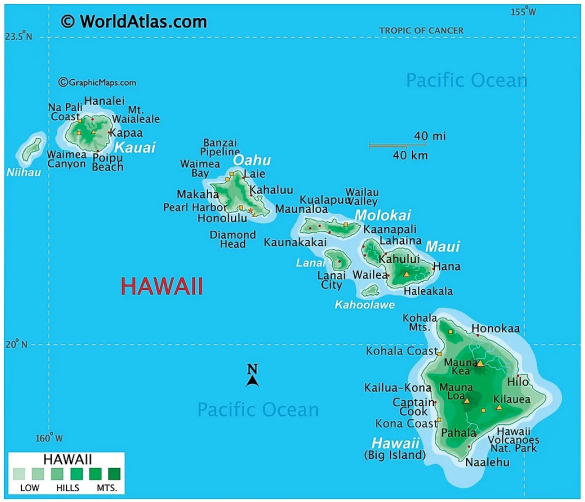
Perelman School of Medicine
University of Pennsylvania

What about legislation?

- 40 states plus District of Columbia require CPR education for all students before HS graduation
  - California – all students who take health ~89% state's students
- Federal laws
  - 1998 Aviation Medical Assistance Act FAA to evaluate AED use on passenger aircraft and airports
  - 2000 Cardiac Arrest Survival Act - placed AEDs in federal buildings and provided civil immunity for authorized users – appropriated $25 mil local grants to purchase AEDs
  - 2002 Community Access to Emergency Devices Act - authorized $30mil in grants to place AEDs in public places and train first responders in AED use and CPR

State laws vary

- All 50 states have Good Samaritan laws applying to AED use
- Hawaii – as of 2015-2016 school year
  - (1) Every public school, charter school, and the University of Hawaii shall have one automated external defibrillator (AED) situated in a permanent location on campus
  - (2) Public schools and charter schools that have athletic trainers, as well as the University of Hawaii, to have an additional AED available at every sporting event
  - (3) Athletic trainers shall be trained and certified on the use of AEDs
  - (4) Public and charter schools that do not have athletic trainers to have at least two faculty members at every sporting event who are trained and certified on the use of AEDs.



IRONMAN WORLD CHAMPIONSHIP MEDICAL SYMPOSIUM
October 20-24,2024
Outrigger Kona Resort, Kailua-Kona Hawai'i

Children's Hospital of Philadelphia
Division of Orthopaedics

Perelman School of Medicine
University of Pennsylvania

Laws are not enough . . .

Emergency Action Plan for Sudden Cardiac Arrest (SCA)

Universal Response to the Collapsed Athlete

Collapsed and Unresponsive*

Assume SCA

***Unresponsive to shoulder tap and verbal stimuli**

Signs of SCA:
Continued respirations/gasping
Seizure-like activity/twitching
Eyes open/rolled back
(Falsely assuming a pulse)

Call EMS

Begin hands-only CPR (chest compressions)

Retrieve and apply an AED as soon as possible

Drezner J. Prevention of sudden cardiac death in athletes: progress and pitfalls (2023 John R. Sutton Clinical Lecture). In: Proceedings of the 2023 ACSM Annual Meeting & World Congresses. 2023 May 31 to June 2: Denver (CO).

AMERICAN COLLEGE of SPORTS MEDICINE LEADING THE WAY

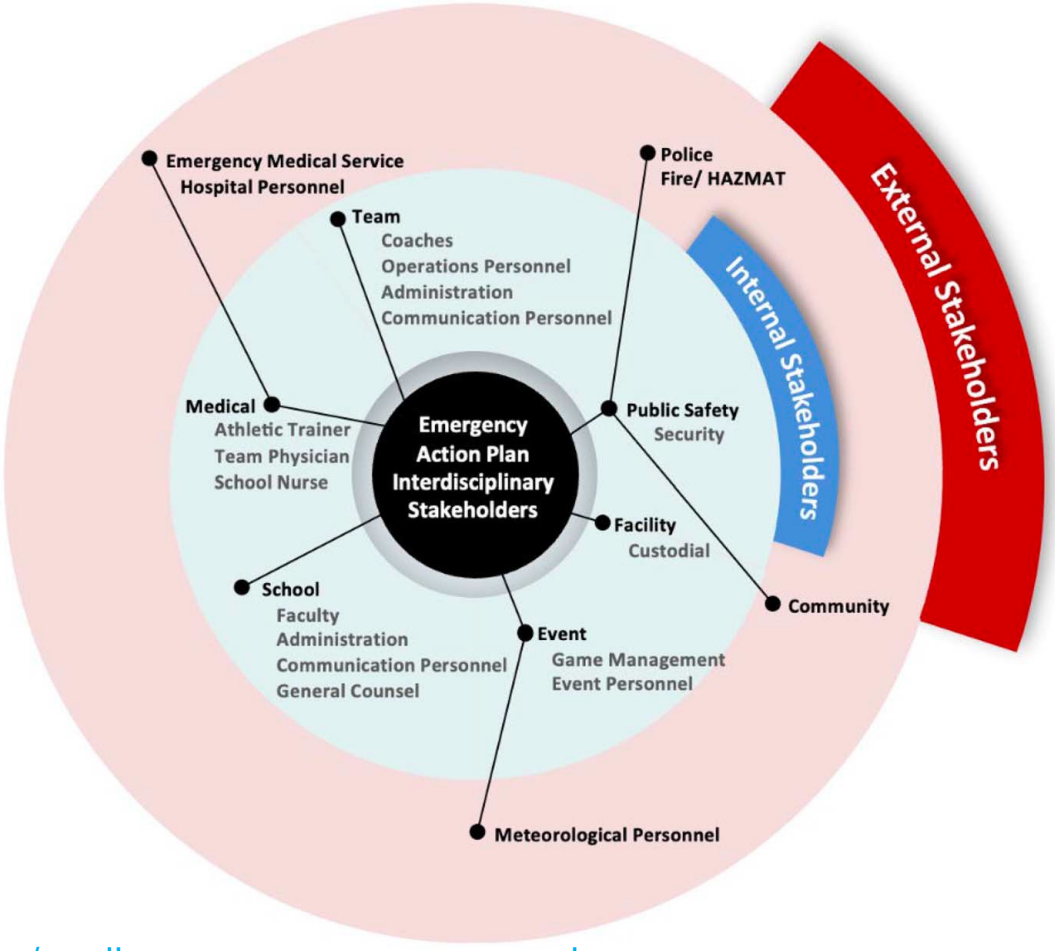
IRONMAN WORLD CHAMPIONSHIP MEDICAL SYMPOSIUM
October 20-24,2024
Outrigger Kona Resort, Kailua-Kona Hawai'i

Children's Hospital of Philadelphia
Division of Orthopaedics

Perelman School of Medicine
University of Pennsylvania

Emergency Action Plan

- Everyone should have one
- Everyone should review it regularly, at least annually
- Everyone should practice it
- Everyone should have pre-game timeouts to review plan for the game
- Everyone should debrief after any event that activates the EAP



https://cpr.heart.org/en/training-programs/cardiac-emergency-response-plan-cerp

Do they work? The impact of AEDs

- Survival rate for SCA decreases 7-10% per minute for each minute from collapse to defibrillation with AED
  - Goal: First shock within 3 minutes collapse
  - Educate general population
  - Deploy in public areas, training and sports facilities
  - 2005 vs 2018 – change in CPR training and AED placement and training– improved survival to hosp d/c from 23.8% to 66.7% for general SCA
- Population-based registry of all paramedic responses for SCA from 2009-2014 - 43.8% of athletes with SCA during competitive sports survived to hospital discharge
- 93% survival SCA Italian sports facilites with AED on site
- 100% survival Japanese athletes witnessed SCA marathon with prompt resuscitation

Shared decision making

Agency for Healthcare Research and Quality

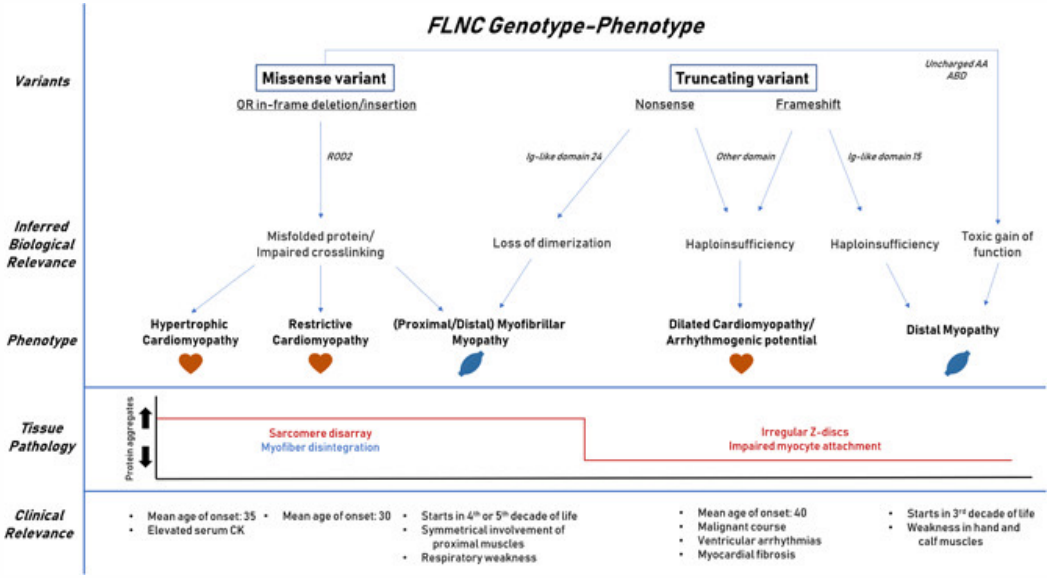
"When a health care provider and a patient work together to make a healthcare decision that is best for the patient. Optimal decision takes into account evidence-based information about available options, the provider's knowledge and experience, and the patient's values and preferences."

What is the risk?

- 0.3% or 3/1000 screened athletes will be identified as possible risk, fewer than 1 per year will have SCD
- Potential harms of testing – heightened anxiety, unnecessary testing, negative changes to lifestyle and adverse economic consequences
- Framing the risk of death – 0.7/100000 person years for SCD
  - Ski/snowboard 0.25/100,000
  - Scuba 3/100,000
  - Mountain hikers 6/100,000
  - Parachutists 18/100,000
  - Mountaineers 600/100,000

Considerations for shared decision-making regarding disqualification based on screening

- Prior cardiac arrest
- Unexplained syncope
- Symptomatic obstructive hypertrophic cardiomyopathy
- Dilated cardiomyopathy
- Significant impairment of systolic function
- High risk genotypes lamin A/C, filamin C



IRONMAN WORLD CHAMPIONSHIP MEDICAL SYMPOSIUM
October 20-24,2024
Outrigger Kona Resort, Kailua-Kona Hawai'i

Children's Hospital of Philadelphia
Division of Orthopaedics

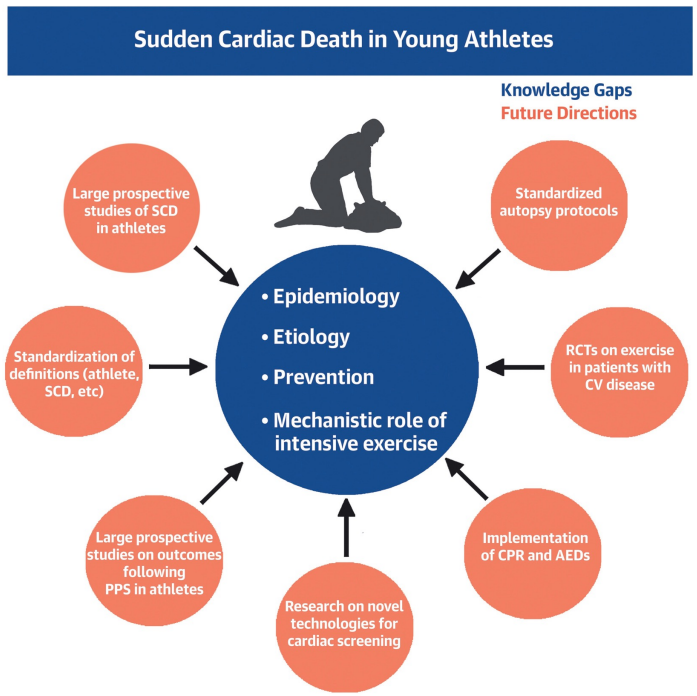
Perelman School of Medicine
University of Pennsylvania

Children's Hospital of Philadelphia
Division of Orthopaedics

Perelman School of Medicine
University of Pennsylvania

Future considerations

CENTRAL ILLUSTRATION: Gaps in Knowledge and Future Directions in Sudden Cardiac Death in Young Athletes



Finocchiaro G, et al. J Am Coll Cardiol. 2024;83(2):350-370.

References

- Han J, Lalario A, Merro E, Sinagra G, Sharma S, Papadakis, M, Finocchiaro G. J Cardiovas Dev Dis. 2023 Feb; 10(2):68. published online 2023 Feb5.
- Peterson DF, Kucera K, Thomas LC, et al. British Journal of Sports Medicine 2021;**55:**1196-1203.
- Arthur MN, DeLong RN, Kucera K, et al. Br J Sports Med 2024;**58**:494–499.
- Krishnan S, Guseh JS, Chukumerije M, Grant AJ, Dean PN, Hsu JJ, Husaini M, Phelan DM, Shah AB, Stewart K, Wasfy MM, Capers Q 4th, Essien UR, Johnson AE, Levine BD, Kim JH; American College of Cardiology Sports & Exercise Leadership Council. JAMA Cardiol. 2024 Jul 17. Epub ahead of print.
- Zane J. Blank, Robert L. Spicer, Jeffrey A. Robinson. Pediatrics January 2023; 151 (1): e2022056798.
- Drezner JA, Sharma S, Baggish A, et al. British Journal of Sports Medicine 2017;**51:**704-731.
- Ghani U, Farooq O, Alam S, Khan MJ, Rahim O, Rahim S. Cureus. 2023 Jun 2;15(6):e39873
- Rose K, Goble M, Berger S, et al. NASN School Nurse. 2016;31(5):263-270.
- Verdonschot JAJ, Vanhoutte EK, Claes GRF, et al. Hum Mutat. 2020 Jun;41(6):1091-1111. doi: 10.1002/humu.24004. Epub 2020 Mar 20.
- Harmon KG, Asif IM, Maleszewski JJ, et al. Circulation. 2015 Jul 7;132(1):10-9.
- Bagnall RD, Weintraub RG, Ingles J, et al. N Engl J Med. 2016 Jun 23;374(25):2441-52.

Thank you!

masterc@chop.edu

@drtinamaster

IRONMAN WORLD CHAMPIONSHIP MEDICAL SYMPOSIUM
October 20-24,2024
Outrigger Kona Resort, Kailua-Kona Hawai'i

Children's Hospital of Philadelphia
Division of Orthopaedics

Perelman School of Medicine
University of Pennsylvania