Objectives**

- List the most common causes of cardiac death etiologies in athletes
- Compare/contrast use of ECG in cardiac screening in athletes
- Identify the historical and clinical exam red flags in screening for cardiac events in athletes

Screening ECG**

- A good screening test should be cost-effective and should influence a disease or health outcome that has a significant impact on public health.
- SCD prevalence is low
- No outcome based data exists as of yet
- Insufficient screening infrastructure
- Discrepancy of risk of screening and follow-up may be higher than actual disease
Our first attempt at getting our hands (and brains) around this topic:

- Sudden Cardiac Death in Athletes
  - Michael Sampson DO and Ed Kornoelje DO
  - Metropolitan Hospital, December 1996

Question:

- What is the goal, reduction of sudden cardiac death (ultimately) or finding athletes at higher risk for sudden cardiac death?
How many are there?

- Approx 60 million 12-25 year olds in US.
- Approx 10 million competitive athletes in this group.

What do they die from?

- HCM
- Coronary Artery Anomalies
- Myocarditis
- Wolff-Parkinson-White Syndrome (WPW)
- ARVC
- Long QT Syndrome
- **Commotio cordis

Incidence of Sudden Cardiac Death in Young Athletes

- Initial estimates put number at 1:200,000 to 1:300,000 in the US.
- More recent US studies put the number closer to 1:50,000.
- The United States Sudden Death in Young Athletes Registry has identified approx 115 cases of SCD per year, or about 1 case of sudden cardiac death every 3 days in US organized youth sports.


Scope of Problem

- Risk (on average): 2 per 100,000 persons per year.
- 2.5X higher than age-matched non-athletes.
- Risk increases with increasing peak intensity of exercise and increasing level of competition.
- Athletes with underlying but undiscovered heart disease may have 100-fold higher risk.


Recommendations and Considerations Related to Preparticipation Screening for Cardiovascular Abnormalities in Competitive Athletes: 2007 Update

- Prevalence of cardiovascular diseases that predispose to sudden cardiac death in the general athletic population is estimated to be 0.3% (3/1000).


- This is confirmed by several other ECG studies with reported true-positive rates of 0.2-0.4%.

Incidence of SCA In HS Athletes (Toresdahl 2013)

- There is no reliable, mandatory SCD/SCA registry in the US.
- Many “studies” use media reports, ins. claims... to determine incidence, and often look at SCD.
- Recent 2 year prospective study using National Registry for AED Use in Sports and 2,149 high schools.
- Data suggests 1:58,000—more than previously suspected—likely underreported.
- Males 5 times higher than females.
- Athletes 3 times higher than non-athletes.

Incidence Pearls

- Incidence estimates are highly variable and largely dependent on study methodology, age, and demographics.
- SCD in athletes is higher in:
  - M>F
  - College>HS
  - Black/African>Caucasian
  - Athletes>non-athletes
  (Exercise is a risk for persons with CV disease)

Should we screen at all?

- Data on ANY type of screen is scarce.
- Screening types often discussed:
  - History and physical
  - ECG
  - Echo
  - Various combo’s of above
- “There is general (although not universal) agreement with the principle that screening to detect important diseases and potentially prevent sudden death is justified and potentially beneficial.”


History and physical: enough, worth it at all?

- “There is general agreement that conducting a comprehensive screening personal and family history and physical examination is useful; however data supporting the efficacy of such a screening strategy alone are limited.”

- Assessment of the 12-Lead Electrocardiogram as a Screening Test for Detection of Cardiovascular Disease in Healthy General Populations of Young People (12-25 Years of Age). Maron et al. JACC (Scientific Statement), 64(14), 2014.
Oh, really?

- The statement goes on to say, “...an important proportion of adolescents and young adults at risks for SD...MAY (emphasis added) have warning signs and symptoms or a positive history... POTENTIALLY (e.a.) detectable by careful evaluation....Although the 12-lead ECG can be regarded as more sensitive than the history and physical, (see next slide) it is nevertheless associated with reduced specificity because of false positive results.”

Specificity Better than Advertised—Why?

- Analysis of H/PE/ECG studies (n=9):
  - H  sens 0-44%  spec 69-99%  PPV 0-4%
  - PE  sens 0-40%  spec 90-100%  PPV 0.6-8%
  - ECG sens 66-100%  spec 84-99%  PPV 3.4-22.5%


Seattle Criteria

- Feb 13/14 2012 an international group of experts in sports cardiology and sports medicine convened in Seattle, Washington to define contemporary standards for ECG screening in athletes.
- Objective of meeting was to develop a comprehensive training resource to help physicians distinguish normal ECG alterations in athletes from abnormal ECG findings that require additional evaluation for conditions associated with SCD.


2014 Refined Criteria

- Authors noted that refining the 2010 ESC Criteria (76.6%) and 2013 Seattle Criteria (87.5%) raised specificity to 94% across all ethnicities and reduced abnormal ECG prevalence rates to 3.6% and 2.1% in Arabic and Caucasian athletes.


  - Slides on “how we got here” are included at end for anyone interested.
Back to the AHA Statement

- “However, the acknowledged insensitivity of the history and physical examination screening cannot be considered a major justification for mass screening of general populations with ECGs.”
- HUH? There is almost universal acceptance that some sort of CV screening should be done, it has been demonstrated that H&P alone are insufficient to do this, advances in screening criteria have made the ECG acceptable from the point of view of sensitivity and specificity, but we shouldn’t do this???

What About HCM?

- HCM appears to be the number one cause of SCD—how does the ECG do with this? H&P (particularly the P—heart murmur) likely will find 25% (maybe 50%) of HCM. ECG will detect up to 90% (10% false neg). What do you think?

Others weigh in:

- “To summarize, screening including an ECG recording has a high sensitivity for underlying disease, but the specificity needs to be improved, whereas screening of athletes without the use of the ECG has a very low sensitivity.”
  - *Sudden Cardiac Death in Athletes*. Schmied and Borjesson. Journal of Internal Medicine, 275, 2014.

ESC Criteria for ECG Interpretation in Athletes: Better But Not Perfect

- “False positive results raise concerns about the unnecessary investigations, erroneous disqualification and psychological harm to the athlete. Conversely, SCDs in sport are highly visible, claiming young lives.”
- “In a cost-prohibitive financial climate the ECG is probably the most effective tool for identifying conditions predisposing to SCD in young athletes.”
Addition of the Electrocardiogram to the Preparticipation Examination of College Athletes

- 2010 study--Stanford University
- “Considering the prevalence of diseases potentially associated with SCD...it has been the consensus of the cardiologists at our institution to recommend that ECG screening becomes mandatory for our athletes...”


More Support


And More


Two More


Italian Data (mandatory ecg screening)**
- Relative risk reduction in SCD by 89%
- MCC of SCD was ARVC (homogeneous Veneto rgn of Italy)
- Data only reflects change in exertional sudden death rate by detection of ARVC and not other etiologies such as WPW, HCM, long QT syndrome
- Poor translation to heterogeneous, mixed US population

Back in the USA...**
- University of Washington
- PPE 4th ed
- Validated role of AED at the field side
- Contributed to the literature on interpretation of the ECG in the athlete
- Suggested that a screening ECG is a potentially valuable adjunct...controversy continues

Big Leagues (AHA and ACC)**
- Chosen NOT to endorse universal ECG screening
- Large false positive rate
- Increased level of anxiety secondary to screening
- Ethical considerations
- Prohibitive cost of large scale screening program

Numbers Game
Incidence of SCD**
- College Athletes: 1 in 50,000
- High School Athletes: 1 in 80,000
- NCAA Div 1 basketball players higher risk: 1 in 5,200 athlete-years (AY) vs general NCAA Div 1 athletes: 1 in 53,703 AY
- Death from Drugs/Suicide essentially same incidence of SCD as athletics
- HCM thought to be the mcc...however not the case
- Death from CAD higher than suspected
- Many SCD causes lack specific cardiac etiologies, thus ECG would not pick them up upon screening
Screening Tests**

- A good screening test should be cost-effective and should influence a disease or health outcome that has a significant impact on public health during the asymptomatic period
- Should be significantly sensitive, specific and acceptable to patients
- Population must have high enough prevalence of disease to be screened
- Patients must be willing to comply with additional evaluation and early treatment

In the UK according to mathematical modeling using Italian data:

- In order to prevent 1 case of SCD, 38K athletes would need to be screened and 800 athletes would be inappropriately excluded from competition (false +).
- WPW, HCM may be detectable with ECG in the asymptomatic period but...save a life or alter the course of disease
- Refined criteria, False + rate drops to 6% however, the false – rate needs to be taken into consideration (not everything can be found in the asymptomatic athlete

Screening Tests**

- Follow up medical care/consult (cardiology)
- Follow up testing (CMR, Echo, etc.)
- Not accessible all athletes due to location or cost
- DQ from sports, but athletes continue outside formal organized sports w/out resources (medical personnel or AED)

Infrastructure

Clinical Agreement**

- Lack of infrastructure in the US to perform screening and follow up testing
- Overlap between physiologic ECG changes in athletes heart vs pathological states
- Specific ECG criteria has been developed and online module is has been created but...
- Only those that are aware of the criteria have the knowledge base and even then, when confronted with uncommon entities, limited interrater agreement increases false + and false – rates which again limits the validity of the ECG as a screening test
- And the lack of widely trained physicians limits screening
Then there is the follow up dilemma**

- An ECG abnormality is ‘found’, then follow up is mandated
- This involves more testing (cost, access)
- The athlete is then labeled and/or disqualified from play
- Risk of testing and/or treatment higher risk than SCD (EP testing, Ablation, Pacemaker implantation, etc)

Show me the money**

- Estimated 8.5 million young athletes in the US
- Cost effectiveness if less than $50K per year of life saved
- Cost of screening ECG along with PPE =$76K (based on ECG of $5 w/ mass setting)
- Average in office ECG is $19-$40/test
- Follow up testing (echo or CMR) was not added to the above
- Free ECG? Who over reads it? Legal climate?
- What interval should screening occur? Yearly? At certain ages? (HCM Autosomal Dominant)
- Issue of falsely labeling an athlete as positive/broken/diseased/play restricted...what is the cost of that

Will screening prevent SCD?**

- Sudden Cardiac Arrest (SCA) will still occur in athletic settings
- Money is better well spent for AED and CPR education
- SCA in the HS setting, 64% survived after discharge if an AED was utilized vs 11% of those who had to wait for EMS and defibrillation was delayed
- AHA endorses AED at every school that cannot guarantee EMS call to shock less than 5min
- This is also supported by multiagency task force along with 15 national sports medicine organizations with AOASM being one of them

Cost Effectiveness Analysis of Screening of High School Athletes for Risk of Sudden Cardiac Death

- 2000 cost-analysis
- “Preparticipation cardiovascular mass screening of high school athletes appears to be best accomplished through performance of ECGs that are twice as cost effective as the American Heart Association-recommended specific cardiovascular history and physical examination. Two-dimensional echocardiography is the least cost effective method. . .”

Cost-Effectiveness of Preparticipation Screening for Prevention of Sudden Cardiac Death in Young Athletes

- Design: Decision-analysis, cost effectiveness model.
- “...ECG plus cardiovascular-focused history and physical examination is reasonable in cost and is effective at saving lives.”
- Similar cost effectiveness as dialysis, public access to defibrillation, and implantable cardioverter-defibrillator implantation.
- Dedicated CV screening with H&P is much more costly and marginally more effective than no screening.


Cost Effectiveness

- Schmied and Borjesson again: “Cost effectiveness studies are always difficult to interpret, but most seem to favour the inclusion of the ECG in screening.”
- AHA 12-Lead ECG statement: significant discussion on cost-effectiveness (CE). Data that suggests favorable CE often use actual data, the arguments against use “theoretical models” and “cost-projection models.” These are important, but I would caution against using cost as the main reason NOT to do something.

Public Health Perspective

- Meningococcal vaccine of all incoming college freshmen may prevent 2-5 deaths a year with a cost per death of $22 to $48 million.
- Disease prevalence of all cardiovascular disorders that predispose young athletes to SCD is 1:333. In US standard newborn screening for phenylketonuria and cystic fibrosis; prevalence of these is 1:15,000 and 1:3500 respectively.
  · Wash State Dept of Health 2008.

Anxiety?

- One suggested concern is anxiety after being told one has an abnormal ECG, either a true- or false-positive. While this possibility needs to be acknowledged, several studies suggest (as we do with any potentially unfortunate news we deliver) that “effective communication was shown to decrease anxiety and other negative effects of false positive screening tests....”
- Discuss the fact that the ECG is an imperfect test which will not pick up all problems, a positive test does not necessarily mean there is a problem, if there is an issue disqualification is unlikely, and that there is no perfect test—this is just one more way to try and find out if they are at risk (just like we have done with the H&P for the last 50 years).
Who else supports?

- ESC
- IOC
- FIFA
- NFL
- MLB
- NHL
- NBA
- MLS
- Harvard U
- Howard U
- U of Wisconsin
- U of Virginia
- Georgetown U
- Stanford U
- U of Washington

Is There Evidence for Mandating Electrocardiogram as Part of the Pre-Participation Examination?

- Items such as liability, erroneously restricting one’s ability to make a living, and negatively impacting public perception of exercise by not reducing SCD or over-restricting participation need to be taken into account.
- “Thus, cardiac pre-participation screening without ECG cannot be recommended given our current knowledge. . .On ethical grounds the reasons (logistical, legal, economic) for not screening individual athletes should be very clearly stated.

Electrocardiograms Should Be Included in Pre-participation Screening of Athletes

“...the consequence of delays in implementing ECG screening until more research data are available would come at the cost of failure to prevent deaths from occurring during the period of time that the study effort is being conducted.”


Further AHA/JACC info (12-Lead article):

- “...screening efforts have benefited some young individuals through identification of potentially life-threatening cardiovascular disorders. Such initiatives have been supported consistently by the 1996 and 2007 AHA Scientific Statements, as well as the present document.”
Middle Ground/Future Direction?

- “While the AHA opposed mandatory or nationalized ECG screening programs, the AHA has long supported ECG programs that are locally driven, well-organized, and with sufficient physician interest and resources.”
- “The lack of a broad physician infrastructure capable of implementing quality ECG programs should not deter recognition that ECG screening better achieves the goals of cardiovascular screening when conducted by experienced clinicians; rather, it should motivate the sports medicine and cardiology communities to reach and establish a new standard for the cardiovascular care of athletes.”

Recommendations (Hainline et al.):

1. Disclose that the ECG has limits for positive and negative predictive accuracy for SCD risk.
2. Interpret with the current (and future evolving) state of knowledge that distinguishes physiological cardiac remodeling from findings suggestive of underlying cardiac pathology.
3. Conduct with adequate cardiology oversight and resources to assist with the secondary investigation of ECG abnormalities. The ECG should be obtained with equipment and by persons trained according to ACC/AHA/Heart Rhythm Society recommendations.
4. Parallel with the development of a registry for research into new knowledge regarding sensitivity and specificity of history, physical examination, and ECG findings to the screening process.

(Almost) Final Thoughts

- In 2016 it appears that consensus is mounting for the use of ECG as part of the PPE (local non-mandated efforts as a start).
- Addition of ECG to PPE in a local/team/school setting appears to be the best method at this time.
- While cost and logistics are important factors, we need to be creative in working around these issues.
- Improvements in screening criteria will likely occur over next few years, reducing the false-positive ECG’s—this has happened—the Seattle Criteria/Revised Criteria.
- More physicians need to take advantage of the BMJ ECG training module...
ECG Module

- Published through the British Medical Journal:
  - learning.bmj.com
  - There will be a click-through to “ECG interpretation in athletes”
  - Free

Questions, so many questions**

- Is there a link between asymptomatic screening ECG findings and improved health outcomes?
- Can all causes of SCD be found on ECG?
- Who is going to pay for the screening AND the second and third order testing and at what risks?
- What are the infrastructure resources needed to conduct ECG screening?

Bottom Line**

- Saving lives goes beyond screening ECG, AEDs, CPR training
- The PPE with thorough Hx and PE is key
- Red flags found during Hx or PE then should proceed to further testing (ECG, lab, etc.)
- Every sports club/organization should have a written Emergency Action Plan (EAP) that is reviewed, updated and rehearsed

Management of SCA in Sport

- Must have emergency action plan and access to AED’s.
- Practice the plan!
- Suspect SCA in any collapsed and unresponsive athlete.
- Seizure=SCA until proven otherwise.
- Abnormal finding ≠ DQ.
- AED programs save lives.
- EAP/AED/CPR!!!
"Do the best you can until you know better. Then when you know better, do better."

- Maya Angelou

Two examples of local initiatives:

The community heart screens are organized by the Nick of Time Foundation (Mill Creek WA), targeted at area high schools, free, and offered about once per month.

http://nickoftimefoundation.org/

Full PPE with ECG. Team of Physicians for Students (TOPS--Phoenix AZ).

http://www.aztops.org/

Key Reference Articles


- Assessment of the 12-Lead Electrocardiogram as a Screening Test for Detection of Cardiovascular Disease in Healthy General Populations of Young People (12-25 Years of Age). Maron et al. JACC (Scientific Statement), 64 (14), 2014.
Key Reference Articles


- February 2013 issue of the British Journal of Sports Medicine has several other related articles.

ADDENDUM: HOW WE GOT HERE

Basis for Meeting (Seattle 2013)

- Sudden cardiac death is the leading cause of death in athletes during sport.
- Whether obtained for screening or diagnostic purposes, an ECG increases the ability to detect underlying cardiovascular conditions that may increase the risk of SCD.
- In most countries, there is a shortage of physician expertise in the interpretation of an athlete’s ECG.
- A critical need exists for physician education in modern ECG interpretation that distinguishes normal physiologic adaptations in athletes from abnormal findings suggestive of pathology.

Thank-you

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Attendees/Groups

- AMSSM
- European Section on Sports Cardiology (EACPR)
- European Society of Cardiology (ESC)
- FIFA Medical Assessment and Research Center (F-MARC)
- Pediatric & Congenital Electrophysiology Society (PACES)
- U of Washington, Mayo Clinic, Stanford, U Conn, Mass General, UCLA, Emory University, Children’s Hospital of Philadelphia, Italy, Belgium, Brazil, Switzerland, UK

Preparticipation Cardiovascular Screening in Young Athletes: Current Guidelines and Dilemmas

2007 AHA Consensus Guideline Update

- AHA 12—key elements of the screening cardiovascular examination.
- National standard for cardiovascular screening.
- Against the use of ECG for routine screening but noted “The AHA panel agreed that non-invasive testing such as the ECG can improve the diagnostic power of the history and physical exam. . . .”


Recommendations and Considerations Related to Preparticipation Screening for Cardiovascular Abnormalities in Competitive Athletes: 2007 Update

“Although the ESC proposal is innovative and based on a generally favorable long-term experience in Italy, it cannot easily be translated into the US medical system and environment. On the other hand, the panel does not arbitrarily oppose volunteer-based athlete screening programs with noninvasive testing performed selectively on a smaller scale in local communities if well designed and prudently implemented.”


The 12-Element (now 14) AHA Recommendations for Preparticipation Cardiovascular Screening of Competitive Athletes

1. Exertional chest pain/discomfort
2. Unexplained syncope/ near-syncope
3. Excessive exertional and unexplained dyspnea/fatigue, associated with exercise
4. Prior recognition of a heart murmur
5. Elevated systemic blood pressure
6. Prior restriction from participation in sports
7. Prior testing for the heart, ordered by a physician
8. Premature death (sudden and unexpected, or otherwise) before age 50 years due to heart disease, in a relative
9. Disability from heart disease in a close relative <50 years of age
10. Specific knowledge of certain cardiac conditions in family members: hypertrophic or dilated cardiomyopathy, long-QT syndrome or other ion channelopathies, Marfan syndrome, or clinically important arrhythmias
11. Heart murmur
12. Femoral pulses to exclude aortic coarctation
13. Physical stigmata of Marfan syndrome
14. Brachial artery blood pressure (sitting position)
Parental verification is recommended for high school and middle school athletes.

Judged not to be neurocardiogenic (vasovagal); of particular concern when related to exertion.

Auscultation should be performed in both supine and standing positions (or with Valsalva maneuver), specifically to identify murmurs of dynamic left ventricular outflow tract obstruction.

Preferably taken in both arms.


The Athlete’s Heart: Remodeling, Electrocardiogram and Preparticipation Screening

- 2002
  - “However, such false-positive, abnormal ECG patterns in athletes are an important limitation to the diagnostic power of the ECG testing in preparticipation cardiovascular screening of large athletic populations.”

Electrocardiography and the Preparticipation Physical Examination: Is It Time for Routine Screening?

- 2006
  - Against including ECG due to cost and high incidence of false-positive results.
  - “These limitations may lead to unnecessary disqualifications and added testing, causing much stress and anxiety for athletes, parents and coaches.”
  - Advocated standardization of PPE on national level.

ECG added to PPE

- 1998 study suggested 77% greater power to detect HCM than than history and physical examination.

- 2006 report of 25 year study of 42,386 athletes in Italy using history/physical/ECG showed 10-fold reduction in the incidence of sudden cardiac death.
Evidence for Efficacy of the Italian National Pre-participation Screening Programme for Identification of Hypertrophic Cardiomyopathy in Competitive Athletes

- 2006 study of 4450 elite athletes.
- Initial screening with history/physical/ECG.
- Follow-up with echo.
- No definite cases of HCM identified (after ECG before echo) although 5-10 would be expected given prevalence of 0.1-0.2%.

Authors suggest:
- ECG screening is effective in leading to the diagnosis of HCM.
- Reason for negligible SCD due to HCM in Italy is due to ECG screening and H&P.
- Not absolutely necessary to utilize echocardiography as a routine diagnostic test for the detection of HCM. May aid in identifying other cardiac issues.

Cardiovascular Screening in College Athletes With and Without Electrocardiography

- Prospective study.
- 508 Harvard collegiate athletes.
- Each received hx/physical/ECG/TTE.
- Those doing H&P blinded to ECG/TTE results.
- H&P found 5/11 abnormalities, adding ECG moved it to 10/11 (sensitivity up from 45% to 90%).
- False-positive rate went from 5.5% to 16.9%.

Performance of the 2010 European Society of Cardiology Criteria for ECG Interpretation in Athletes

- 508 university athletes.
- 11 had findings suggestive of or diagnostic for cardiac disease relevant to sport participation risk.
- 3 met criteria for restricted sports participation.
- 505/508 cleared were followed for 2 years without any cardiac events.
Performance of the 2010 European Society of Cardiology Criteria for ECG Interpretation in Athletes

- 62/508 were found to have abnormal findings
  - 13: H&P
  - 29: ECG
  - 20: H&P and ECG
- 49 (9.6%) had abnormal ECG with 2010 criteria (down from 83 (16.3%) with 2005 criteria).
- Sensitivity (low rate of false negatives) remained high (.909) and specificity (false positives) improved (from .169 to .100) or from 83% to 90%.

NCAA ECG Study—Multicenter Feasibility Trial in DI Schools

- Purpose: to evaluate and compare the accuracy of cardiovascular screening in NCAA athletes using a standardized history, physical exam, and ECG (using Seattle Criteria).
- Ongoing—14 NCAA DI schools-now expanding to DII and III.
- Any athlete without prior ECG screening was eligible.
- PPE insensitive for conditions associated with SCD.
- Incidence of SCD in DI athletes 4-5 times higher than previously thought (Harmon 2011).
- ECG has potential to increase detection of athletes at risk.
- Concerns for false-positive results, unnecessary secondary investigations or disqualification, and cost.

NCAA ECG Study—Multicenter Feasibility Trial in DI Schools

- 2,471 male and female athletes screened.
- 7 athletes (.28%) diagnosed with serious cardiac conditions.
- All 7 had abnormal ECG’s.
- 2 had abnormal H or P.
- 4 athletes were upperclassmen with previous normal H&P.
- More data coming in but it appears false positive rate about 3% with ECG and 30% with H.
NCAA ECG Study—Multicenter Feasibility Trial in DI Schools

- Limitations: larger sample size needed for accurate prevalence, potential for false-negatives, low false-positive rate may not be reproducible with less experienced interpretation.
- Conclusions: feasible, low false-positive with new criteria, superior accuracy compared to H&P alone.
- Greater physician infrastructure needed to apply accurate use of ECG.