The Cardiovascular Risks of Diving

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&

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Conflicts of Interest

- **Research Support:** **NHLBI, NIAMS, NCCAM,** GlaxoSmithKline, Merck, Roche, Pfizer, AstraZeneca, B. Braun, Genomas, Hoffman-LaRoche
- **Consultant:** Astra Zenica, Merck, Schering-Plough, Takeda, Roche, Genomas, Abbott, Runners World
- **Speaker Honoraria:** Merck, Pfizer, Abbott, Astra Zenica, GlaxoSmithKline
- **Stock Shareholder:** Zoll, General Electric, JA Wiley, Zimmer, J&J

Conflicts of Interest

I Am A Member of Both Pam Douglas' and Fred Bove's Fan Clubs

Introduction

- 26% of Diving Fatalities Are Attributed to CVD
- PubMed Search in Feb 2010 Using "Diving" & "Cardiac Events" Yielded 25 Publications…1 Relevant
- Whereas "Exercise" & Cardiac Events" Yielded 3,501 Publications
- This Presentation Will Address Non-Diving, Exercise-Related Events
- To Develop Strategies Applicable to Diving-Related Cardiac Events

I Think I Know How Wayne Newton Must Feel in Las Vegas

I Have Sung The Same Songs A Lot !

Circulation
JOURNAL OF THE AMERICAN HEART ASSOCIATION

American Heart Association.
Learn and Live.

Exercise and Acute Cardiovascular Events: Placing the Risks Into Perspective: A Scientific Statement From the American Heart Association Council on Nutrition, Physical Activity, and Metabolism and the Council on Clinical Cardiology

In Collaboration With the American College of Sports Medicine, Paul D. Thompson, Barry A. Franklin, Gary J. Balady, Steven N. Blair, Domenico Corrado, N.A. Mark Estes, III, Janet E. Fulton, Neil F. Gordon, William L. Haskell, Mark S. Link, Barry J. Maron, Murray A. Mittleman, Antonio Pelliccia, Nanette K. Wenger, Stefan N. Willich and Fernando Costa

Circulation 2007;115;2358-2368; originally published online Apr 27, 2007;
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What Causes Death During Physical Exertion ?

In The "Young"
(< 30, 35, 40 yrs)

In "Adults"

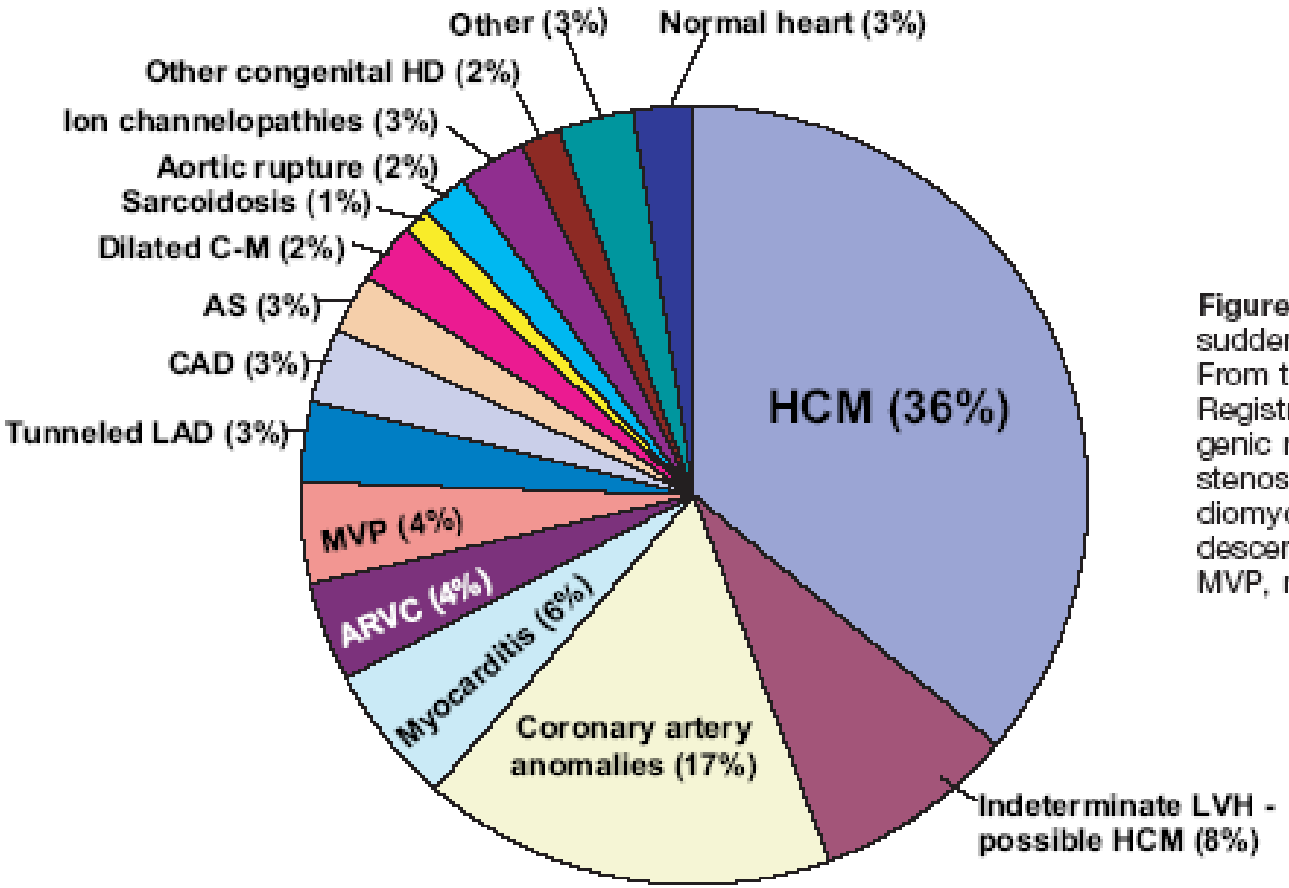


Figure. Distribution of cardiovascular causes of sudden death in 1435 young competitive athletes. From the Minneapolis Heart Institute Foundation Registry, 1980 to 2005. ARVC indicates arrhythmogenic right ventricular cardiomyopathy; AS, aortic stenosis; CAD, coronary artery disease; C-M, cardiomyopathy; HD, heart disease; LAD, left anterior descending; LVH, left ventricular hypertrophy; and MVP, mitral valve prolapse.

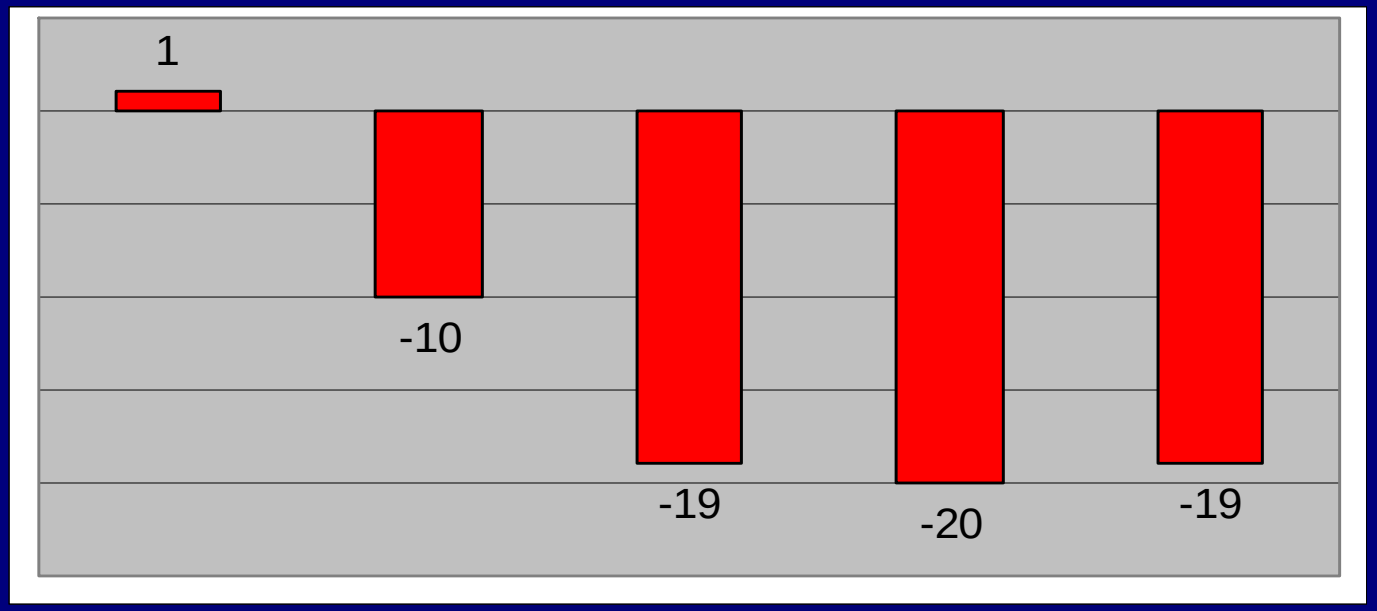
Maron, Thompson, et al Circulation 2007

In Adults ?

- Almost Always Atherosclerotic Disease
- Coronary Artery Disease

In Mutiple Studies Habitual Physical Activity Is Associated with Reduced Atherosclerotic Disease Events

Harvard Alumni Study



<500 –1000 –2000 –3000 >3000

KCalories Per Week

Lee & Paffenbarger 2001

But Vigorous Physical Activity Acutely and Transiently Increase the Risk of Acute Myocardial Infarction and Sudden Cardiac Death (SCD) in Both Young and Older *Susceptible* Individuals

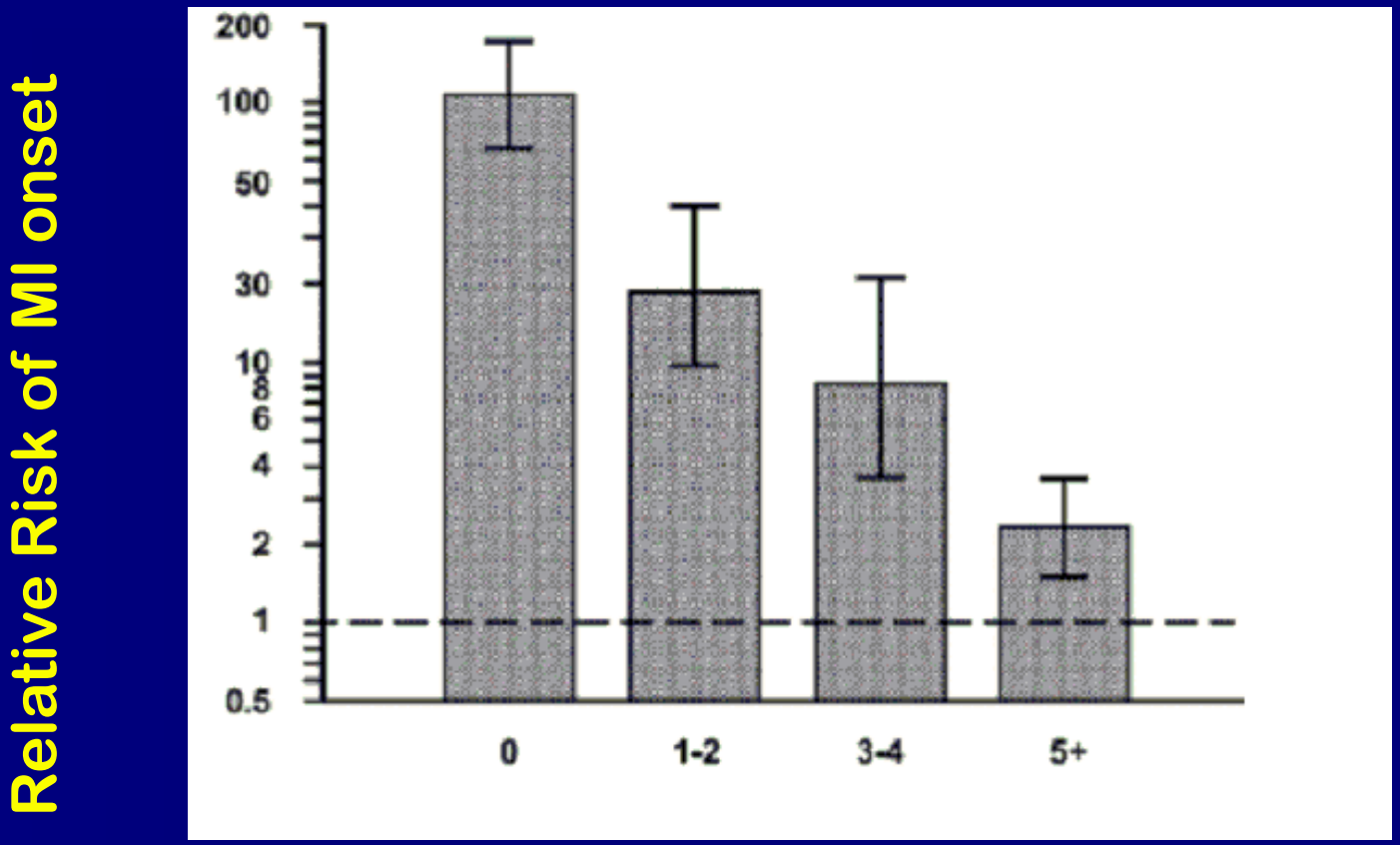
Exercise Benefit And Risk of Cardiac Arrest

Min/Wk	Incidence	Exercise RR	Annual Rate
0	18	-	-
1-19	14	56	17,000
20-139	6	13	23,000
>140	5	5	13,000

Siscovick NEJM 1984

Exercise Also Increases the Risk of Myocardial Infarction

And MI May Equal "Death" During Diving If It Becomes a Disabling or Panic - Producing Event



Mittleman et al, NEJM 1993

Clinical and Angiographic Characteristics of Exertion-Related Acute MI

Giri, Thompson, et al ***JAMA 1999***

Exercise - Related MI

- **Consecutive Series of Acute MI's Treated by PTCA**
- **Activity by LRC and Framingham PAI**
- **Risk factors by Chart Review and History**
- **Qualitative Coronary Angiography**

Giri et al *JAMA 1999*

Relative Risk of EX MI by LRC Activity Level

Very Low	**30.5**	**(4.4 – 209.9)**
Low	**20.9**	**(3.1 – 142.1)**
Moderate	**2.9**	**(0.5 – 15.9)**
High	**1.2**	**(0.3 – 5.2)**

Giri et al *JAMA 1999*

How Dangerous is Exercise ?

How Dangerous Is Exercise For Healthy Adults?

	1 Death Per Year
Per	
Thompson JAMA 247:2535,1982	15,640
Siscovick NEJM 311:874,1984	18,000

How Dangerous Is Exercise For Healthy Adults?

1 Death Per

Thompson

JAMA 247:2535,1982

792,000 Hours of

Exercise

Exercise Event Rates Are Higher in Populations With Known Disease

TABLE 2. Summary of Contemporary Exercise-Based Cardiac Rehabilitation Program Complication Rates

Investigator	Year	Patient-Exercise Hours	Cardiac Arrest	MI	Fatal Events	Major Complications*
Van Camp and Peterson[35]	1980–1984	2 351 916	1/111 996†	1/293 990	1/783 972	1/81 101
Digenio et al[36]	1982–1988	480 000	1/120 000‡	1/160 000	1/120 000	
Vongvanich et al[38]	1986–1995	268 503	1/89 501§	1/268 503§	0/268 503	1/67 126
Franklin et al[37]	1982–1998	292 254	1/146 127§	1/97 418§	0/292 254	1/58 451
Average		1/116 906	1/219 970	1/752 365	1/81 670	

*MI and cardiac arrest.
†Fatal, 14%.
‡Fatal, 75%.
§Fatal, 0%.

Thompson et al Circ 2007 Events

But What About Exercise – Related MI ?

Among 3617 men in the Lipid Research Clinics Primary Prevention Trial 62 (1.7%) sustained an exercice – related AMI (n-54) or SCD (n-8) definitely during a mean follow-up of 7.4 years. 225 men had events not related to exercise, but activity of 170 other men was unclear. These results suggest that 0.2% of hypercholesterolemic men have an exercise-related event annually.

And 99.8% Do Not

But What About Exercise – Related MI ?

Exercise-related AMI also may be substantial in the general population. Using the incidence of SCD among healthy subjects from RI and the observation that exercise-related AMI is 6.75 times more frequent than SCD, the annual incidence of exercise-related AMI could range from 1 AMI per 593 - 3852 apparently healthy middle-aged men.

Incidence of Cardiac Diving Events Seems Quite Low

- Among 590 Diving Fatalities
- 27% Were Possibly Cardiac (Denoble. *Diving and Hyperbaric Medicine*. 2008)
- Using the 7-year Diving Fatality Rate of 16.4 / 100,000 persons (Denoble. *Diving and Hyperbaric Medicine*. 2008)
- The Rate is Only 0.6 per 100,000 divers
- Or 1 Death / 166,666 divers - About 1/2 the Cardiac Rehabilitation Rate

STRATEGIES TO REDUCE EXERCISE-RELATED CARDIOVASCULAR EVENTS

- Restrict High Risk Subjects
- Perform Preparticipation Exercise Testing Prior to Exercise
- Exclude Subjects With Established CVD
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- Prepare for Cardiovascular Emergencies

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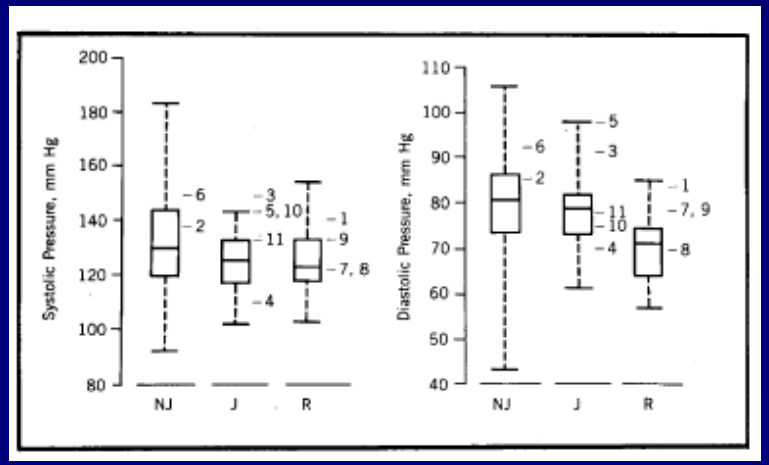
Restrict High Risk Subjects

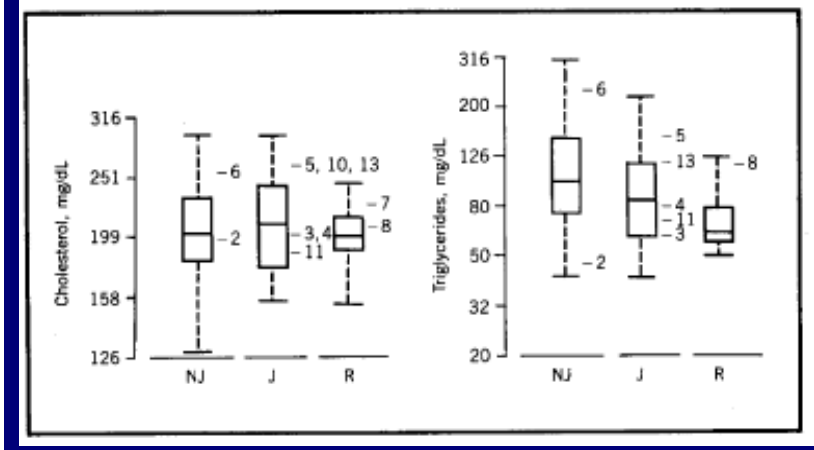
- Problem #1: CAD is so Prevalent That The Majority of Events Occur in Subjects with Modest Risk
- Problem #2: This Strategy Has Not Worked Retrospectively

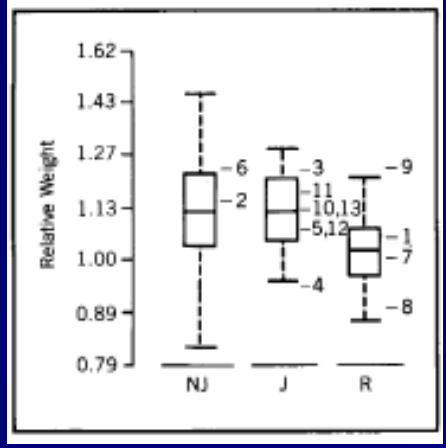
Death During Jogging or Running

A Study of 18 Cases

Paul D. Thompson, MD; Michael P. Stern, MD; Paul Williams, MS; Kirk Duncan, MD; William L. Haskell, PhD; Peter D. Wood, DSc







(JAMA 242:1265-1267, 1979)

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Pre Participation Exercise Testing

- ACC/AHA 2002 -- (Circulation 2002; 2002;106:1883-1892)
- Diabetic Men >35 yrs, Type II > 10 yrs, Type I >15 yrs, any additional CAD RF, Micro Disease
- US Preventive Services Task Force -- Insufficient Evidence to Determine Risk/Benefit (*Ann Intern Med.* 2004;140:569-572)

Exercise Testing for Asymptomatic Persons Without Known CAD

Class 2 - Conflict or Divergence of Opinion

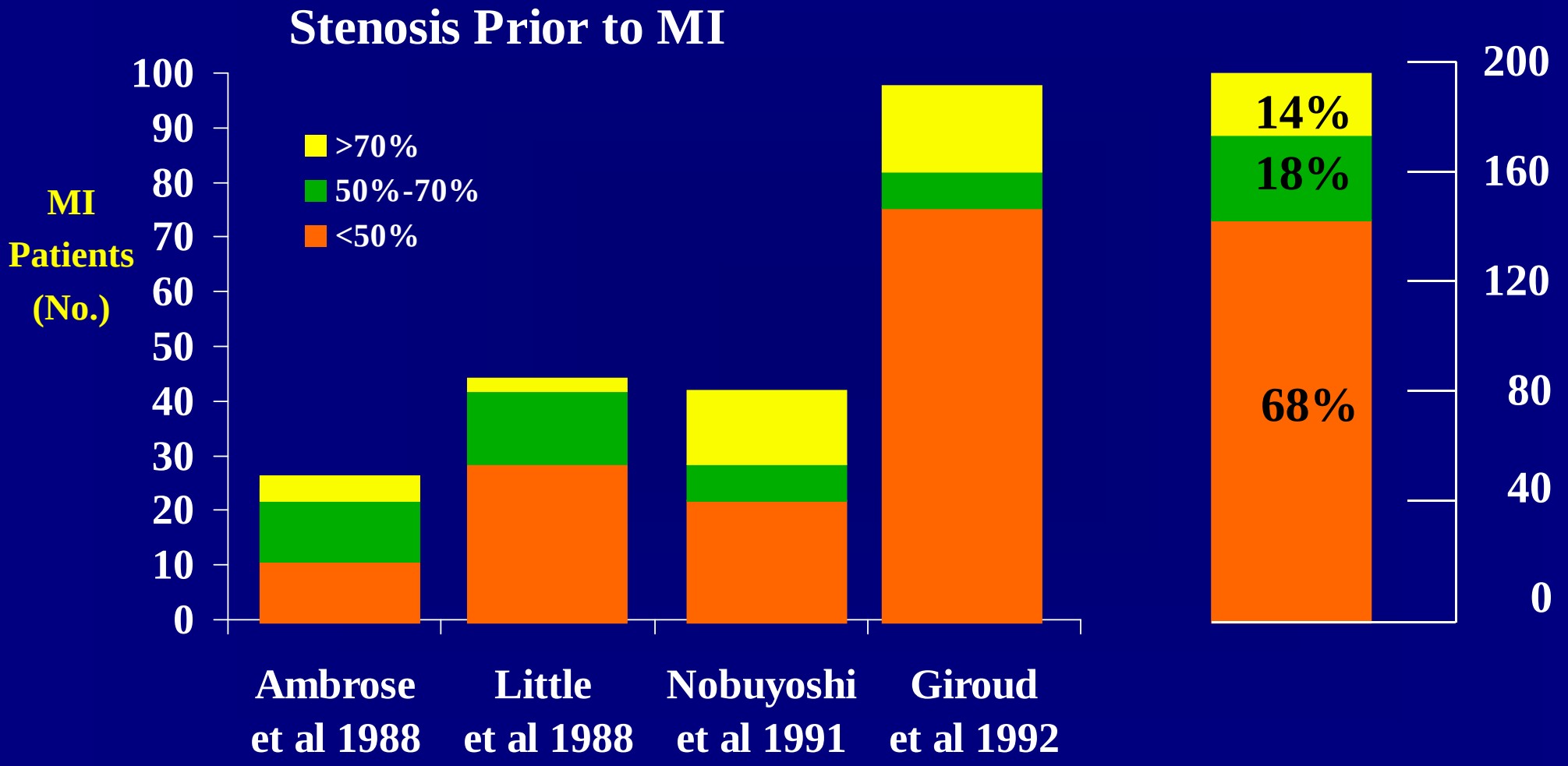
a. Evidence/Opinion Favors - Diabetes Pre Vigorous Exercise

b. Usefulness Less Established - Men >45, Women >55 Pre Vigorous Exercise

Problems With Screening Exercise Tests

- True Positive Results Require A Flow Limiting Lesion
- But Most Events are Caused by Previously Non-Limiting Vulnerable Plaques
- True Positive Results in Asymptomatic Subjects Are Better Predictors of Angina Than MI or SCD
- Possibly Because Asymptomatic, Flow-Limiting Lesions Prompt Collateral Development.

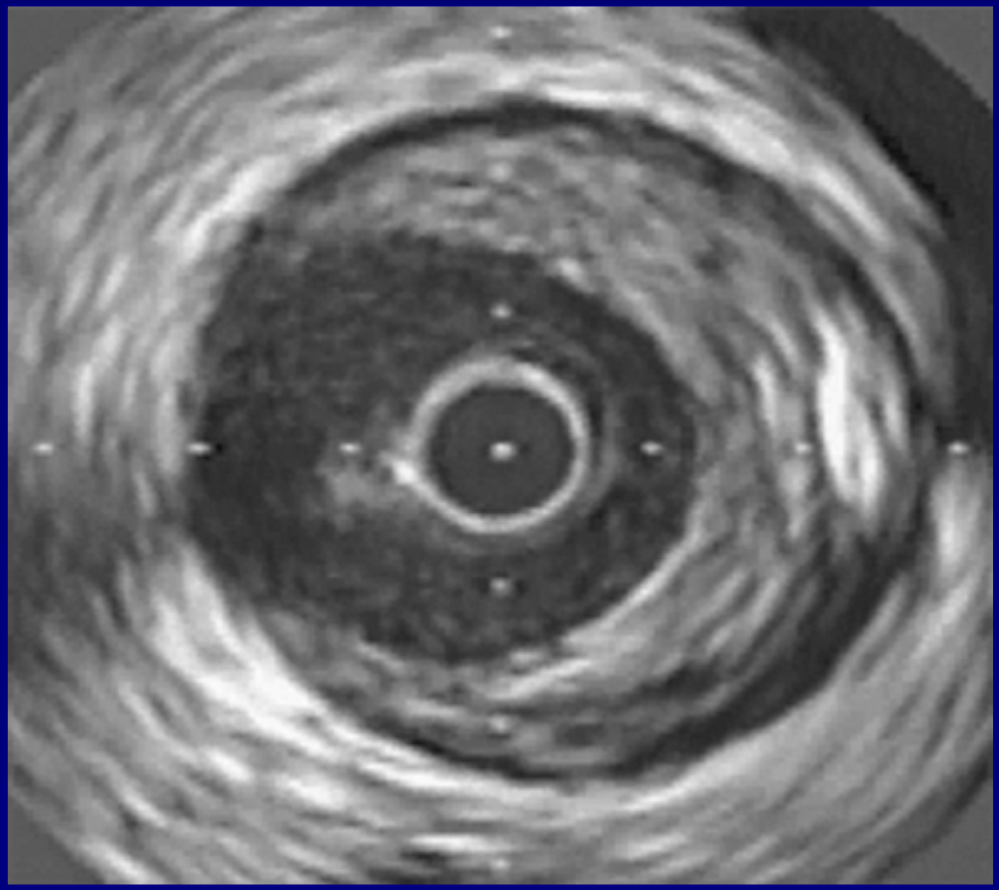
Most MIs Are Caused by Lesions of Minimal Stenosis



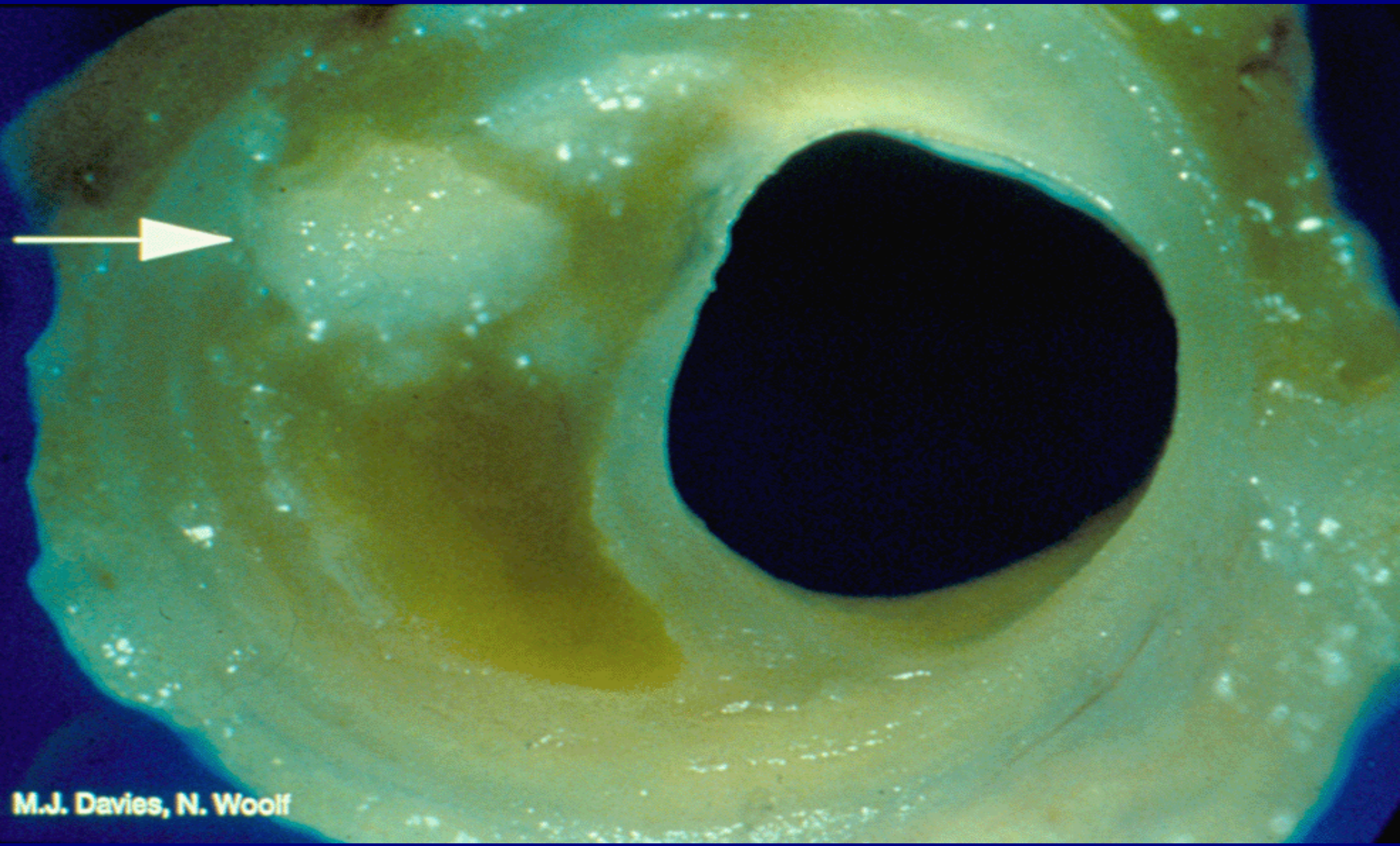
MI=myocardial infarction

Falk E. et al *Circulation*. 1995;92 ;657-671.

IVUS Reveals Angiographically Invisible Lesions



Images Images courtesy of Steven E. Nissen MD,
Intravascular Ultrasound Laboratory, Cleveland Clinic courtesy of Steven E. Nissen MD,
Intravascular Ultrasound Laboratory, Cleveland Clinic


M.J. Davies, N. Woolf

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- Possibly Asymptomatic, Flow-Limiting Lesions Prompt Collateral Development.

Exercise Testing in Healthy Men

916 Healthy Men, 27 - 55 yrs.
Followed 8 - 15 yrs.

23 Initial (+) EXT
- 8 Angina
- 1 Sudden Death

38 New (+) EXT
- 10 Angina
- 1 MI
- 1 Sudden Death

833 Normal EXT
- 12 Angina
- 25 MI
- 7 Sudden Death

McHenry, et al CIRC 70:547, 1984

Sure, The Relative Risk is Higher

Positive Tests

$$\frac{21}{61} = 34\ \%$$

Negative Tests

$$\frac{44}{833} = 5\ \%$$

RR = 6 x Higher

But, Remove Angina

Positive Tests	Negative Tests
$\frac{3}{61} = 5\ \%$	$\frac{32}{833} = 4\ \%$

RR = 1.2

Is an Exercise Tolerance Test Indicated Before Beginning Regular Exercise? A Decision Analysis

Dror Lahav, MD[1], Moshe Leshno, MD[2], and Mayer Brezis, MD, MPH[3,4,5]

RESULTS: Routine screening decreases mortality in intermediate to high-risk populations but not in low-risk persons. At all risk levels, the number of exercise-induced deaths prevented is less than the added number of deaths from angiography. Utility analysis indicates inferiority of routine screening, regardless of risk. Personal preferences (perceived stigma from having coronary disease and perceived benefit of regular exercise on quality of life) have a strong influence on the optimal choice.

CONCLUSION: Routine screening before initiating regular exercise is not recommended for the purpose of reducing the risk of sudden death during exercise training.

J Gen Intern Med 24(8):934–8

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Exclude Subjects with CVD

- Prior CAD May Be The Most Discriminating Factor for Exercise-Related Cardiac Events
- In A Case Controlled Study of 57 Exercise-Related Cardiac Events Vs 42 Controls
- Prior CVD had a 32-fold (95% CI=7 to 143) Increased Risk of an Exercise Event

Risk factors for exercise-related acute cardiac events. A case–control study

W M van Teeffelen,[1] M F de Beus,[2,3] A Mosterd,[2,3,4] M L Bots,[2] W L Mosterd,[5] J Pool,[6] P A Doevendans,[4] D E Grobbee[3]

Table 2 Distribution of determinants across case–control status and univariate relationships with acute coronary event

	Cases*	Controls*	OR#	Multivariable OR
Past Medical History				
History of cardiovascular disease	30/57	3/57	20 (5.6 to 71.5)	32.6 (7.4 to 143)
History of referral to cardiologist	22/57	10/57	3.0 (1.2 to 7.0)	
History of other significant diseases	15/57	11/57	1.5 (0.6 to 3.6)	
Declaration of unfitness for military services	8/57	10/57	0.8 (0.3 to 2.1)	
Consultation of a medical specialist in the last 2 years	27/57	9/57	4.8 (2.0 to 11.6)	
Hospital stay in the last 2 years	14/57	7/57	2.3 (0.9 to 6.3)	
Visit to general practitioner in the last month	12/53	2/54	7.6 (1.6 to 35.9)	
Restriction of physical activity as judged by general practitioner	15/52	1/37	14.6 (1.8 to 116.3)	
Cardiac risk factors				
Family history of cardiovascular disease	29/57	17/57	2.4 (1.1 to 5.3)	
Family history of cardiovascular death	15/56	7/57	2.6 (0.9 to 7.0)	
Smoking	30/57	16/57	2.8 (1.3 to 6.2)	5.9 (1.9 to 18)
Hypertension	19/57	13/57	1.7 (0.7 to 3.9)	
BMI>25 (kg/m²)	26/53	23/55	1.3 (0.6 to 2.9)	
Symptoms				
Chest discomfort	24/57	6/57	6.2 (2.3 to 16.7)	
Shortness of breath	7/57	2/57	3.9 (0.8 to 19.4)	
Palpitations	16/56	5/57	4.2 (1.4 to 12.3)	
Fainting	18/57	5/57	4.8 (1.6 to 14.1)	
Any of these symptoms ever	38/57	14/57	6.1 (2.7 to 13.9)	
Any of these symptoms in the last month	4/57	1/57	4.2 (0.5 to 39.0)	
Fatigue last month	20/57	1/57	30.3 (3.9 to 235.3)	12 (1.2 to 118)
Flu-like symptoms	13/57	1/56	16.3 (2.0 to 129.1)	13.4 (1.4 to 131)

*Values are number of cases/total number of subjects

Br J Sports Med 2009;43:722–725

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Identify Those With Possible Cardiac Prodromal Symptoms

- Multiple Studies Have Identified Prodromal Symptoms Prior to Exercise Related Events
- 50% of Joggers, 75% of Squash players, 81% of Distance Runners Had Probable Prodromal Cardiac Symptoms Prior to Their Exercise-Related Death
- 10% of 159 "Cardiac" Diving Fatalities Had Reported Dyspnea, Fatigue, Chest Ppain, Distress or Illness
- The Specificity of Such Complaints is Poor
- Nevertheless, Inquiry into Prodromal

Risk factors for exercise-related acute cardiac events. A case–control study

W M van Teeffelen,[1] M F de Beus,[2,3] A Mosterd,[2,3,4] M L Bots,[2] W L Mosterd,[5] J Pool,[6] P A Doevendans,[4] D E Grobbee[3]

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Prepare for Cardiovascular Emergencies

Dah !

Suggested Approach

1. Require medical clearance for individuals with known CVD
2. Train Diving Supervisors to Elicit Possible Cardiac Prodromal Symptoms & Require Their Clearance
3. Require Cardiac Emergency Training & Scheduled Drills for Diving Supervisors

The Cardiovascular Risks of Diving

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