Endurance Training and Your Heart
- Insight from the Marathon Runners and
- Ultra-endurance athletes

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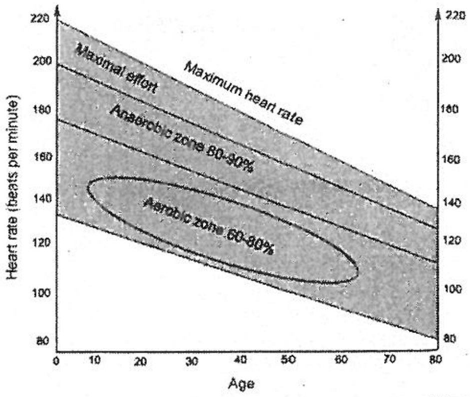
BENEFIT OF EXERCISE
Regular exercise extends 7 years of life expectancy

Disease or Condition	Number of Studies	Trends Across Activity or Fitness Categories and Strength of Evidence
All-cause mortality	***	↓↓↓
Coronary artery disease	***	↓↓↓
Hypertension	**	↓↓
Obesity	***	↓↓
Stroke	***	↓
Peripheral vascular disease	*	→
Cancer		
Colon	***	↓↓↓
Rectal	***	→
Stomach	*	→
Breast	**	↓
Prostate	***	↓
Lung	*	↓
Pancreatic	*	→
Type 2 diabetes mellitus	**	↓↓
Osteoarthritis	*	→
Osteoporosis	**	↓↓

*Few studies, probably less than 5; **approximately 5 to 10 studies; ***more than 10 studies.

CV Endurance Training – Aerobic Zone



PRO-CAR

Cardio vs Endurance

- Individuals exercising regularly live 7 years longer
- This is achievable with modest doses of exercise amounting to 6 – 10 METS per day (metabolic equivalents).
- The majority of highly trained athletes exercise intensively for several hours per day, resulting in workloads of 200 – 300 METS per week which is 5 – 10 times greater than the exercise recommendations for preventing coronary atherosclerosis.

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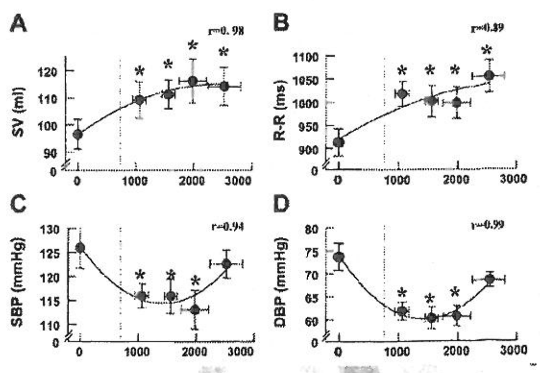
Dose-response relationship of the cardiovascular adaptation to endurance training in healthy adults: how much training for what benefit?

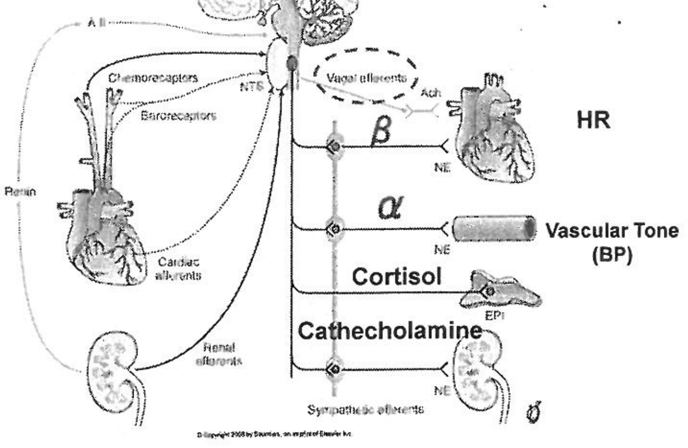
Ken-ichi Iwasaki, Rong Zhang, Julie H. Zuckerman and Benjamin D. Levine

J Appl Physiol 95:1575-1583, 2003. First published 27 June 2003; doi:10.1152/japplphysiol.00482.2003

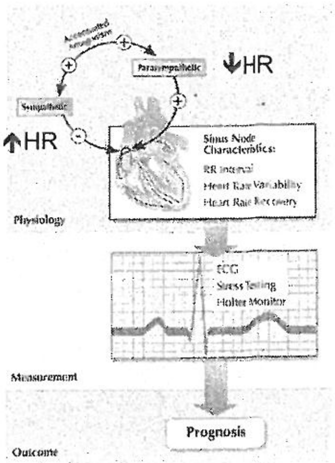


PRO

Autonomic Nervous System



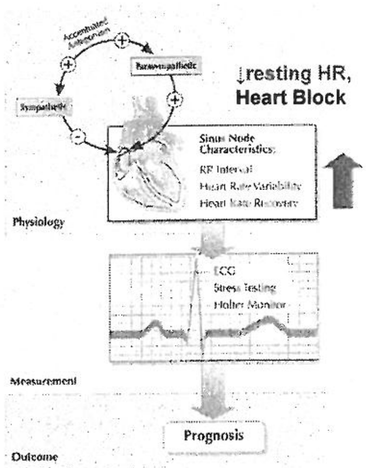
Autonomic Nervous System
&
Cardiovascular Response



Lahiri, M. K. et al. J Am Coll Cardiol 2008;51:1725-1733

Regular Endurance training=>
Enhanced Vagal Modulation

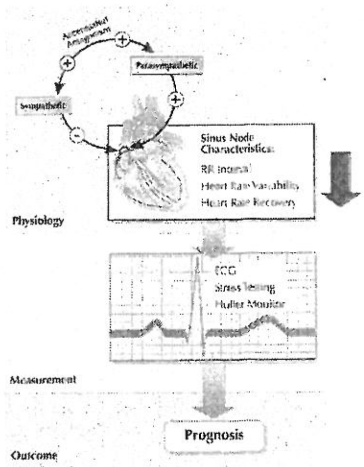
Autonomic Nervous System
&
Cardiovascular Response



Lahiri, M. K. et al. J Am Coll Cardiol 2008;51:1725-1733

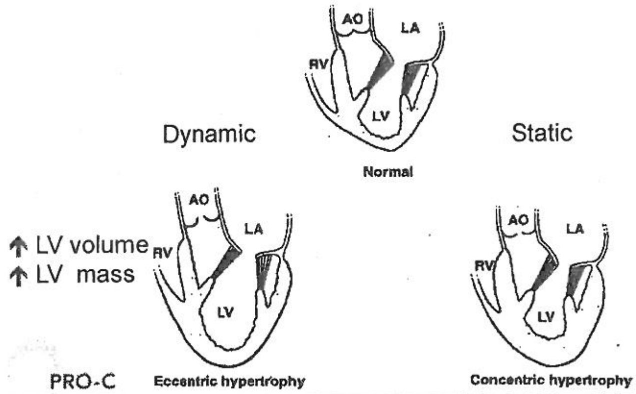
Excessive intensive exercise
Or overtraining =>
Sympathetic predominance

Autonomic Nervous System
&
Cardiovascular Response



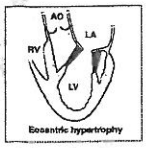
Lahiri, M. K. et al. J Am Coll Cardiol 2008;51:1725-1733

Endurance training leads to heart (LV) enlargement



PRO-C

Eccentric Hypertrophy increases Stroke Volumes



Stroke Volume = blood volume ejected in one heart beat

Subjects	SV Rest	SV Max
Untrained	50-70ml	80-110ml
Trained	70-90	110-150
Highly Trained	90-110	150-220

Eccentric hypertrophy:

- the left ventricle to stretch more and fill with more blood
- wall thickness increases enhance contractility.

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Cardiac Output
= Stroke Volume x Heart Rate

Stroke Volume: blood volume ejected in one heart beat

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Endurance exercise increases Blood Volume

- endurance training increases blood plasma volume (↑ ADH, Aldosterone, ↑plasma proteins).
- pseudoanemia despite RBC count increases,
- Blood viscosity ↓- improvement of circulation).
- ↑ Plasma volume→ V_{O2} max increase

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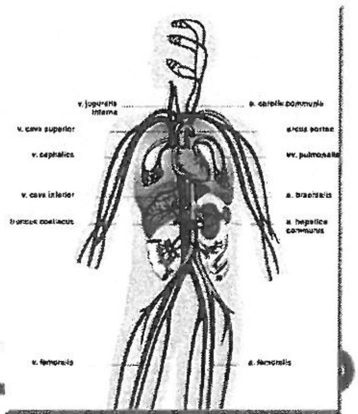
Endurance training increase a-v O2 diff

The Fick Equation

In the 1870's Cardiovascular physiologist A. Fick developed a formula that allows the rate of oxygen consumption (VO_2) to be determined if the cardiac output (Q) and arterial venous oxygen difference (a-v O_2 diff) are known:

VO_2 = Q x a-v O_2 diff



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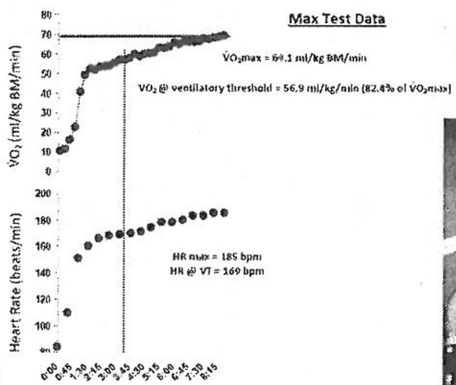
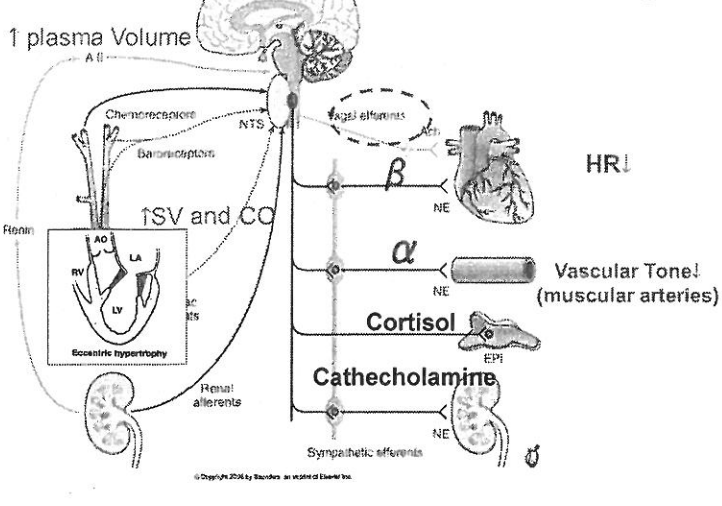
Maximum Oxygen Uptake (VO_{2max})
VO_2 = SV↑ x HR x a-v O_2 diff↑



Endurance Training



Cardiovascular Adaptations to Training

- Left ventricle size and wall thickness increase.
- Resting, submaximal, and maximal stroke volume increases.
- Maximal heart rate stays the same or decreases.
- Cardiac output is better distributed to active muscles and maximal cardiac output increases.
- Blood volume increases, as does red cell volume, but to a lesser extent.
- Resting blood pressure does not change or decreases slightly, while blood pressure during submaximal exercise decreases.

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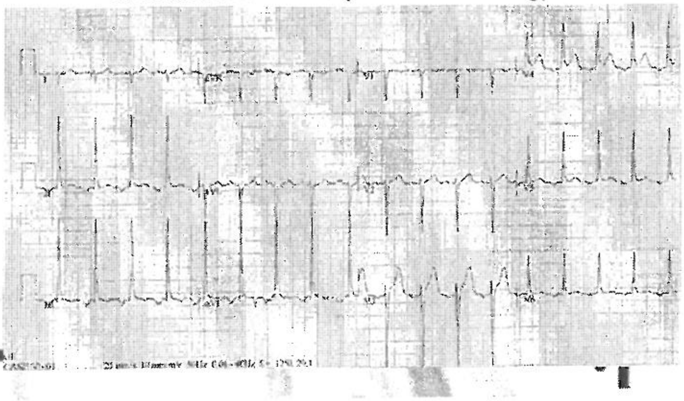
M/41, former Olympic triathlon, regular training and competition. Stopped training for 3 weeks after a minor surgery. Developed fast resting HR (105 bpm) and increased BP (140/100 mmHg)



Detraining for two weeks:

Rapid rebound of Sympathetic and suppression of vagal tone

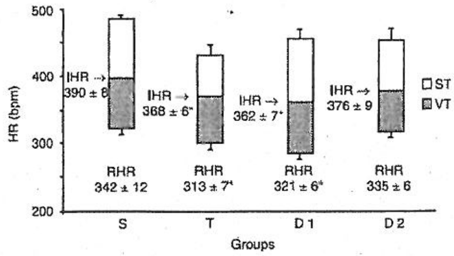
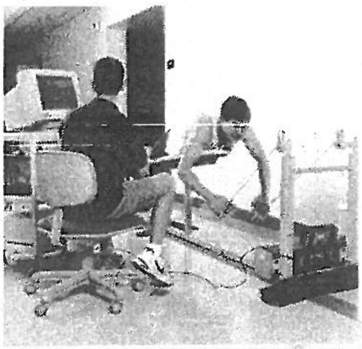
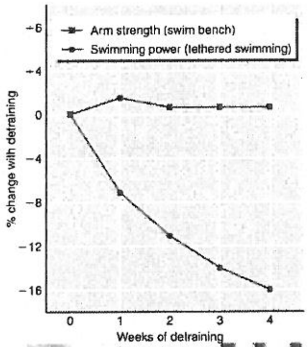


Figure 1. Vagal (VT) and sympathetic (ST) tone and resting heart rate (RHR) in sedentary (S) and trained (T) rats, and in rats detrained for 1 week (D1) and for 2 weeks (D2; see Material and Methods for calculation). IHR = intrinsic heart rate. Data are reported as means ± SEM. *P ≤ 0.05 vs S rats (one-way ANOVA). Note that exercise training induced resting bradycardia, which was paralleled by a reduction in IHR. Of interest, the partial reversal of RHR to pre-exercise training levels was associated with an increased IHR.

Biokinetic Swim Bench and Strength Changes
Detraining





Physiological effects of 2-4 weeks of DETRAINING

$VO_2 = SV \times HR \times$ a-v O_2 diff

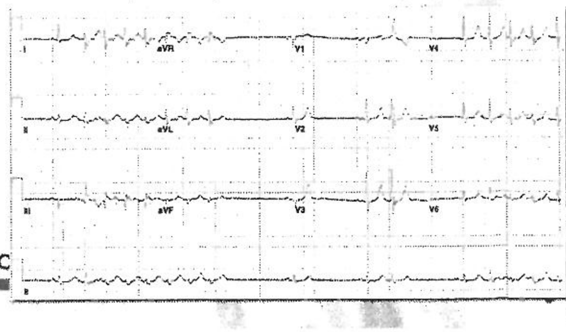
- VO2 max: down 4-15%
- Blood volume: down 5-10% (within 2 days)
- Heart rate: up 5-10%
- Stroke volume: down 6-12%
- Flexibility: Decreases
- Lactate threshold: Decreases
- Muscle glycogen levels: down 20-30%
- Aerobic enzyme activity: Decreases
- Running economy: Unchanged

Athletes' Heart

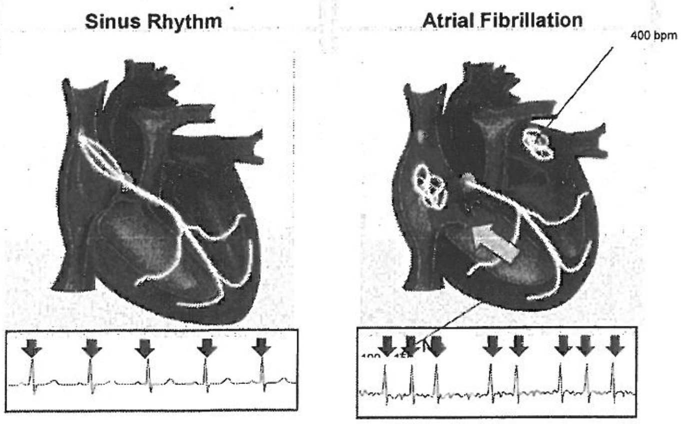
- Left Ventricular Hypertrophy (eccentric)
- Effect of high vagal tone (usually disappears with exercise)
  - Slow HR at rest ,rarely < 40 bpm
  - Extra Beats
  - Conduction defects
- Arrhythmia, esp. Atrial Fibrillation

45 yo male badminton coach

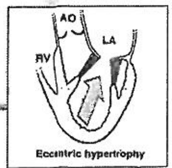
- Recurrent palpitation, mostly at night
- Seldom have attacks during exercise.
- ECG: paroxysmal atrial fibrillation.

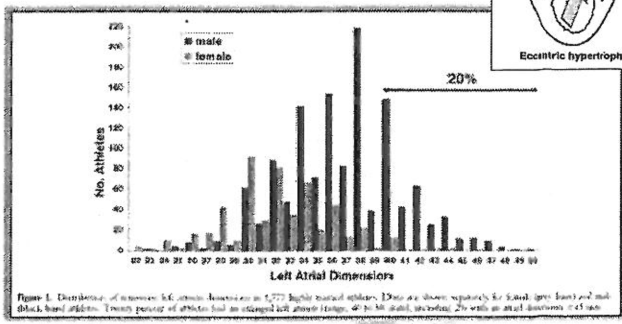


Atrial Fibrillation 心房顫動
LV hypertrophy in Athletes ↑ atrial stretch



Left atrial remodeling in competitive athletes





Pelliccia A et al. *JACC* 2005;46

According to the GIRAFA study,
Vagal AF is the rule rather than the exception in Lone AF
(70% of consecutive LAF patients had vagal AF).

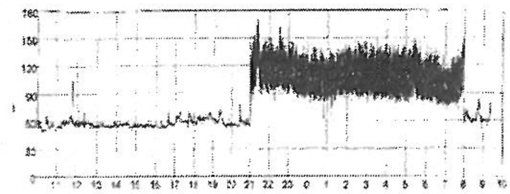


Figure 4 Twenty-four hours recording of heart rate showing a nocturnal episode of atrial fibrillation.

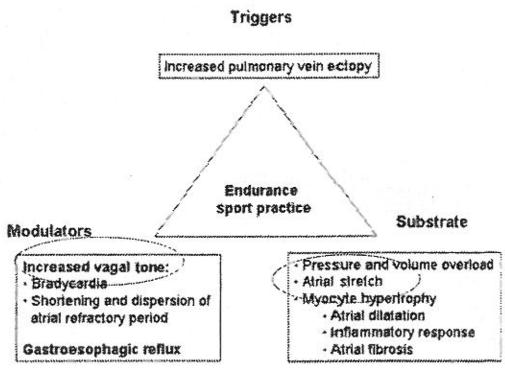


Figure 3 Classical triangle of Coumel suggesting possible etio-pathogenic factors influencing the development of atrial fibrillation in athletes.

Meta-analysis of the risk to develop atrial fibrillation comparing athletes with the general population

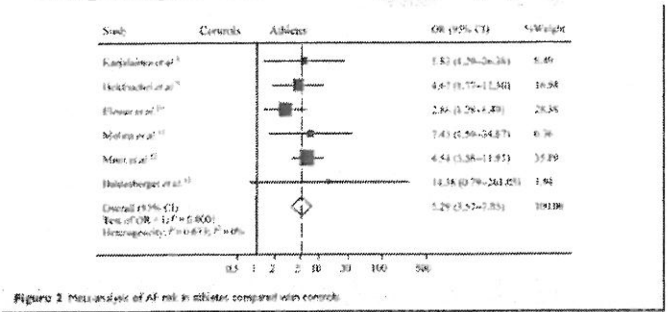


Figure 2 Meta-analysis of AF risk in athletes compared with controls.

AF is 5 times more common in athletes

Abdulla J et al. *Europace* 2009; 11: 1156-1159

AF risk seems to confined to serious athletes who train most days of the week for decades.

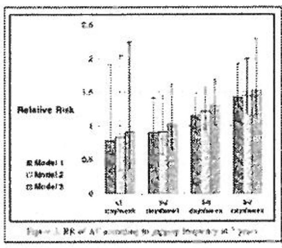


Table 5 Adjusted odds ratios and 95% confidence intervals of lone atrial fibrillation for cumulated moderate and heavy physical activity, height, and left atrial anteroposterior diameter

	Odds ratio (95% confidence interval)	P-value
Cumulated moderate and heavy physical activity		
0–2077 h	1	
2078–9318 h	5.60 (1.59–19.75)	0.0075
≥9319 h	15.11 (3.75–60.83)	0.0001

Mont L. el al *Europace* 2008; 10: 15-20

'Paradox of Exercise'
運動的悖論

- 大量的體力消耗會增加所有人對突發性心臟猝死的短期性風險，但同時卻為那些定期運動(不論是劇烈或非劇烈運動)的人提供對這種風險的保護。
- Vigorous physical exertion increases the short term risk of sudden cardiac death in all people, yet simultaneously offers protection from this risk in those who exercise regularly, while they are both active and sedentary.

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Maron BJ (2000) The paradox of exercise. *N Engl J Med* 343: 1409–1411

1896 Olympic Marathon

Marathon running The legend:

22 miles run from the plains of Marathon to the city of Athen to report the victory of the Athenian army over the Persians. Upon his arrival, Pheidippides exclaimed "Rejoice,we conquer" and drop dead.

The difference between the mile and the marathon is like burning your finger with a match vs being slowly roasted over hot coals

- Hal Higdon

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Exercise Induced C-Troponin Elevation
心肌酶指數是其中一種可界定急性心臟病發的指標之一

Table 1 Recent Studies Examining Post-Exercise cTn Levels

Activity First Author (Ref. #)	Distance	Number of Participants	Troponin Isoform Measured	cTn Diagnostic Threshold	Prevalence of Positive cTn Observed
Walking					
Eijsvogels et al. (48)	30-50 km (4 consecutive days)	103	cTnI	>0.01 ug/ml	18%
				>0.2 ug/ml	6%
Running					
Lippi et al. (45)	HM	17	cTnT	0.03 ng/ml	0%
Jassal et al. (49)	HM	61 (HM)	cTnT	"Detectable"	HM: 30.6% immediately after race; 45.9% at 1 h after
	FM	68 (FM)			FM: 35.7% immediately after race; 52.8% at 1 h after
Mingels et al. (36)	FM	85	hs-cTnT	>99th percentile	86%
			cTnI	>99th percentile	45%
Fortescue et al. (37)	FM	482	cTnT	>0.01 ng/ml	68%
Mousavi et al. (38)	FM	14	cTnT	>0.01 ng/ml	100%
Middleton et al. (2)	FM	9	cTnT	>0.01 ug/ml	100%
Scott et al. (50)	160 km	25	cTnT	>0.01 ug/ml	20%
Giannitsis et al. (51)	216 km	10	hs-cTnT	>99th percentile	50%
Cycling					
Serrano-Ostariz et al. (52)	206 km	91	cTnI	>0.04	43%
Triathlon					
La Gerche et al. (53)	IM	26	cTnI	>0.16 ng/ml	58%

Studies after 2006.
cTn = cardiac troponin; cTnI = cardiac troponin I; cTnT = cardiac troponin T; FM = full marathon (26.2 miles/42.2 km); HM = half marathon (13.1 miles/21.2 km); hs-cTnT = highly sensitive pre-commercial assay from Roche Diagnostics (Basel, Switzerland); IM = ironman distance (swim = 2.2 miles/3.8 km, cycle = 112 miles/180 km, run = 26.2 miles/42.2 km).

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doi:10.1093/eurheartj/ehr397

CLINICAL RESEARCH

Exercise-induced right ventricular dysfunction and structural remodelling in endurance athletes

André La Gerche[1,2]*, Andrew T. Burns[3], Don J. Mooney[3], Warrick J. Inder[1], Andrew J. Taylor[4], Jan Bogaert[5], Andrew I. MacIsaac[3], Hein Heidbüchel[2], and David L. Prior[1,3]

[1]University of Melbourne Department of Medicine, St Vincent's Hospital, 29 Regent Street, Fitzroy VIC 3065, Australia; [2]Department of Cardiovascular Medicine, University Hospitals Leuven, Herestraat 49, 3000 Leuven, Belgium; [3]Cardiology Department, St Vincent's Hospital, 41 Victoria Parade, Fitzroy VIC 3065, Australia; [4]Alfred Hospital and Baker IDI Heart and Diabetes Institute, Commercial Road, Melbourne VIC 3004, Australia; and [5]Radiology Department, Medical Imaging Research Center, University Hospitals Leuven, Herestraat 49, 3000 Leuven, Belgium

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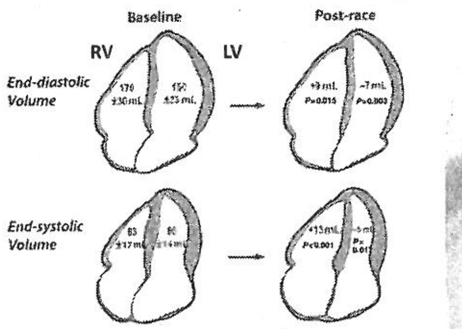
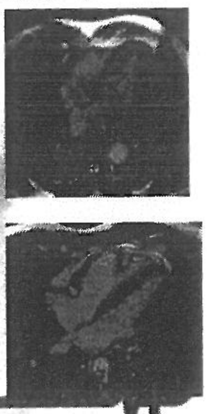
Exercise Induced Right Heart Dysfunction
右心室功能受損, 左心室功能正常





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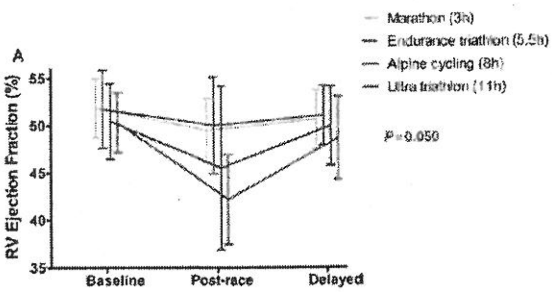
Degree of RV Dysfunction correlated To the Intensity of endurance Exercise
右心室功能的損傷隨著耐力運動的強度和持續時間增加而增加



At Rest:

PA Pressure:
5-10 mmHg

Systemic Pressure:
100-140 mmHg

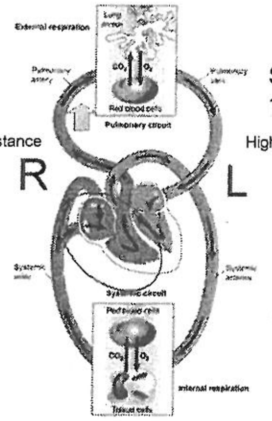
Low resistance

High resistance

High Intensity Exercise:

80 mmHg+

200mmHg+



Myocardial Fibrosis (Scarring) on MRI
心肌纖維化 (磁力共振)

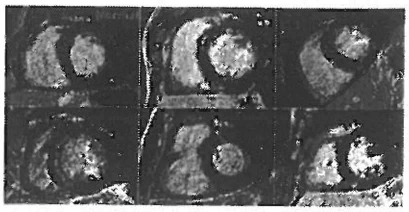


Figure 3 Delayed gadolinium enhancement in five athletes. Images of five athletes in whom focal delayed gadolinium enhancement (DGE) was identified in the interventricular septum (indicated with arrows) when compared with an athlete with a normal study (top left).

5/40 (12.5%) had evidence of permanent damage

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Article

Diverse patterns of myocardial fibrosis in lifelong, veteran endurance athletes

M. Wilson[1], R. O'Hanlon[2,3], S. Prasad[3], A. Deighan[4], P. MacMillan[5], D. Oxborough[6], R. Godfrey[7], G. Smith[7], A. Maceira[8], S. Sharma[9], K. George[10], and G. Whyte[10]

An unexpectedly high prevalence of myocardial fibrosis (50%) was observed in healthy, asymptomatic, lifelong veteran male athletes….. suggesting a link between lifelong endurance exercise and myocardial fibrosis…

長期跑馬拉松的年長選手(即使表面健康、毫無病徵)，逾半人士有心肌纖維化現象。反映長跑對心臟健康有長遠負面影響

馬拉松過度訓練可致心臟纖維化
醫生：賽前檢查心臟 量力而為

心血管疾病患者未必有病徵

心臟電腦掃描結果準確快捷

健康講座

馬拉松與心血管健康實前檢查的重要性

日期及時間：2012年1月6日(星期五) 晚上7時
2012年1月13日(星期五) 晚上7時
2012年1月14日(星期六) 下午3時

報名電話：2506 0626

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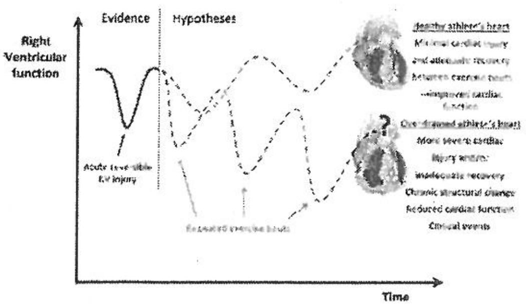

Figure 1 Potential impact of repeated bouts of ultra-endurance exercise on right ventricular structure and function.

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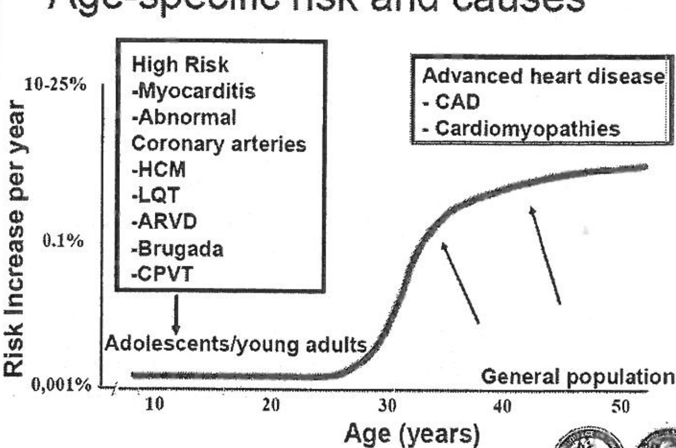
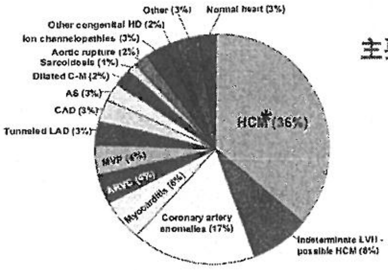
Age-specific risk and causes



發生在年輕運動員的突發心臟猝死

Minneapolis Heart foundation Registry:
SD in 1435 young competitive athletes (1980-2005)

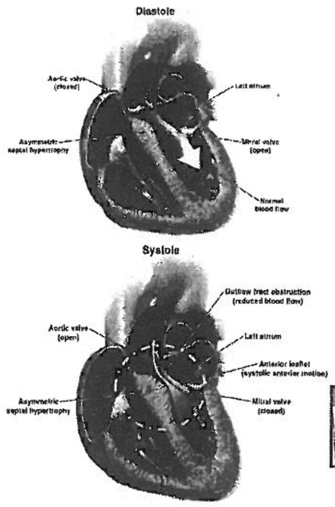


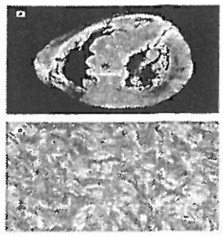
< 35歲以下

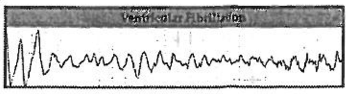
主要是先天性/結構上的缺陷：

- Cardiomyopathy:
  - Hypertrophic 心肌肥厚症
  - Arrhythmogenic RV 右心室發育異常
- Coronary anomaly
- Ion channelopathy 離子通道

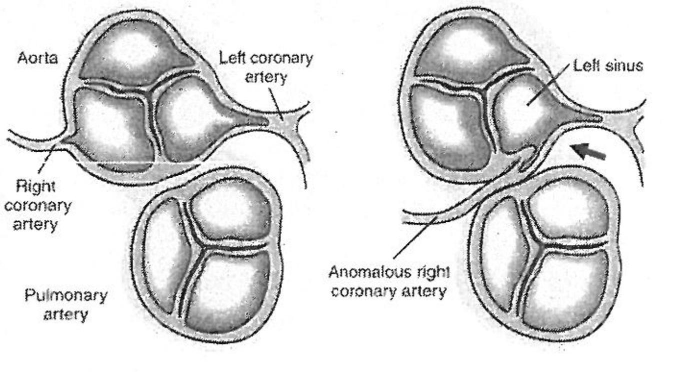
Hypertrophic Cardiomyopathy 心肌肥厚症







Coronary Anomaly 冠狀動脈異常

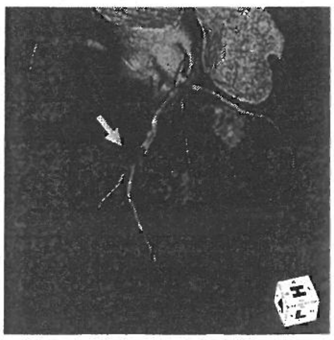


D Normal anatomy

Anomalous right coronary artery arising from the left sinus Valsalva

運動猝死

- > 35歲以上
- 冠狀動脈疾病 90%以上
- 大多數有可識別的冠狀風險因素



Cardiac CT

The 12-Element AHA Recommendations for Preparticipation Cardiovascular Screening of Competitive Athletes, 2007 Update

Medical history*

Personal history

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

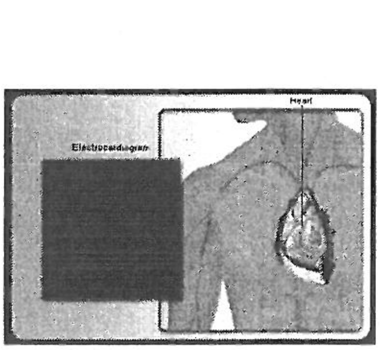
Family history

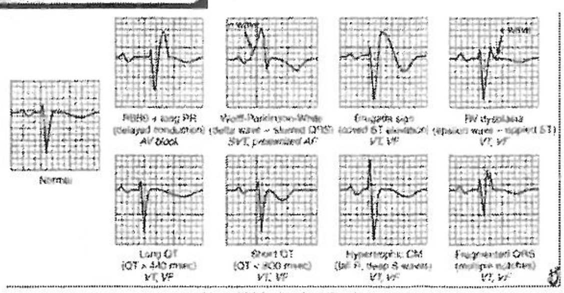
6. Premature death (sudden and unexpected, or otherwise) before age 50 years due to heart disease, in ≥1 relative
7. Disability from heart disease in a close relative <50 years of age
8. Specific knowledge of certain cardiac conditions in family members: hypertrophic or dilated cardiomyopathy, long-QT syndrome or other ion channelopathies, Marfan syndrome, or clinically important arrhythmias

Physical examination

9. Heart murmur‡
10. Femoral pulses to exclude aortic coarctation
11. Physical stigmata of Marfan syndrome
12. Brachial artery blood pressure (sitting position)§

與突發性心臟猝死有關的異常心電圖

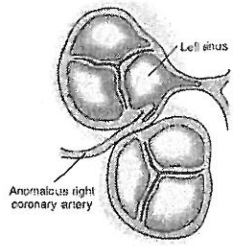


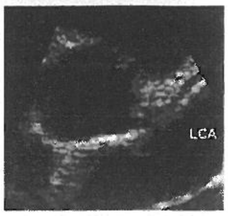


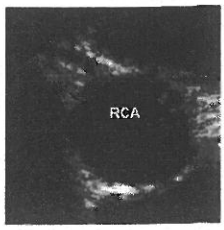
Pre-participation Evaluation

For Young Competitive Athletes

超聲波心動圖

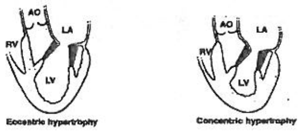




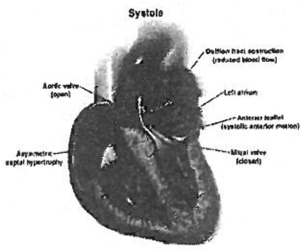


超聲波心動圖

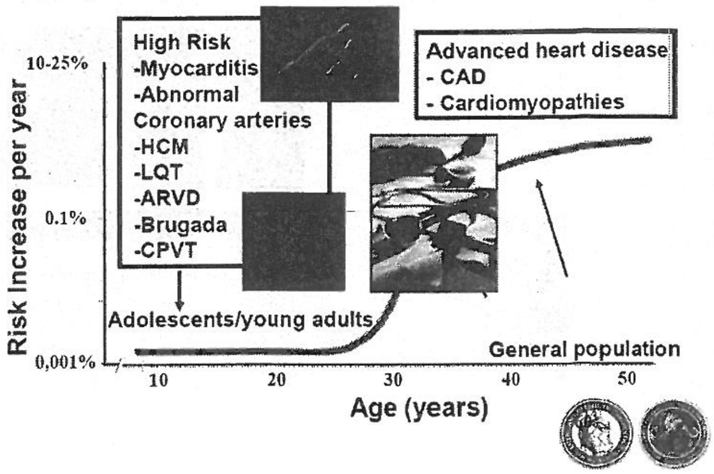
Athletes' Heart Syndrome
運動員心臟綜合症



心肌肥厚症

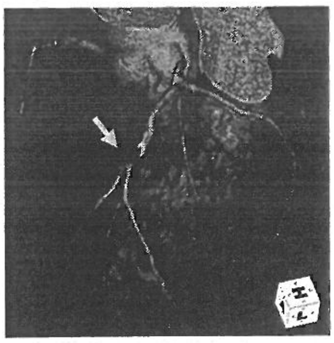


Age-specific risk and causes



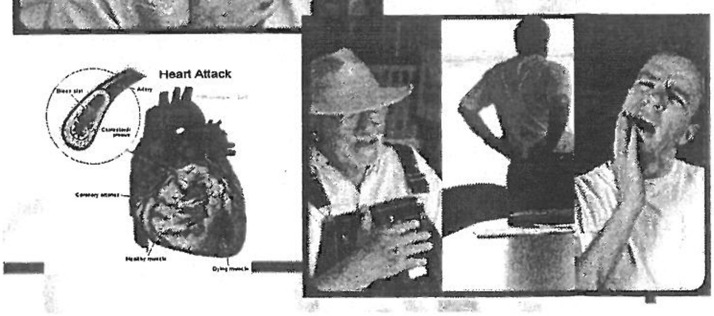
Exercise Sudden Cardiac Death (2)

- <u>> 35 years of Age</u>
- Coronary Artery Disease (CAD) >90%
- Most have recognizable coronary risk factors

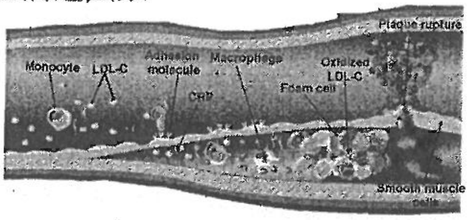


Cardiac CT

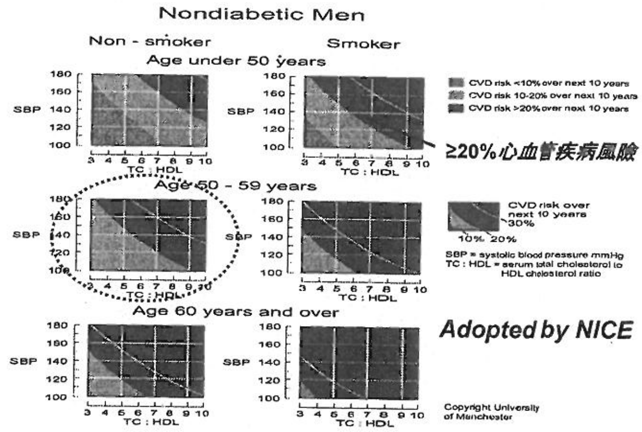
Angina



患心血管病之因素



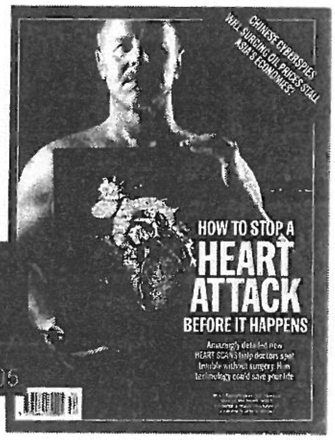
Joint British Societies 的心血管疾病的風險圖



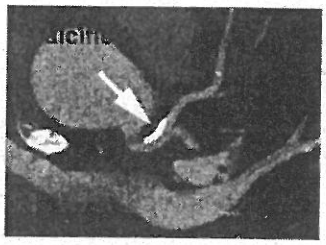
Adopted by NICE

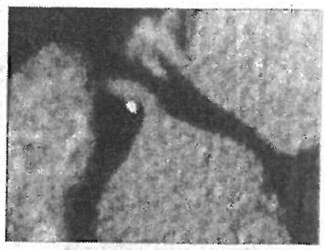
CCTA for detection of CAD

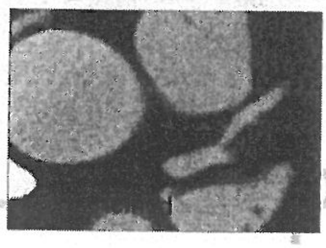
Multislice Spiral (64 slices) CT



....TIME 2005





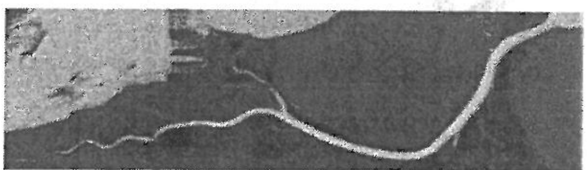


Visualization of non-stenotic plaque by CT

PRO-CARDIO 心滙

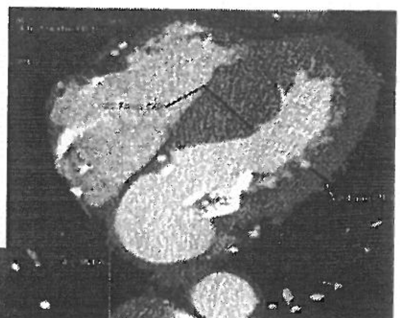
Negative Predictive Valve 100%
陰性預測值達100%

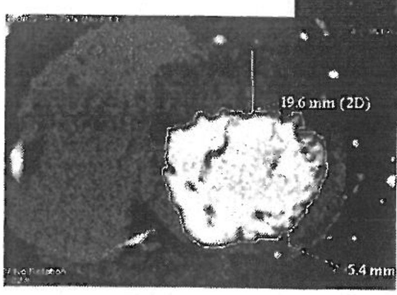
Negative CCTA Rule Out Significant CAD



PRO-CARDIO 心滙

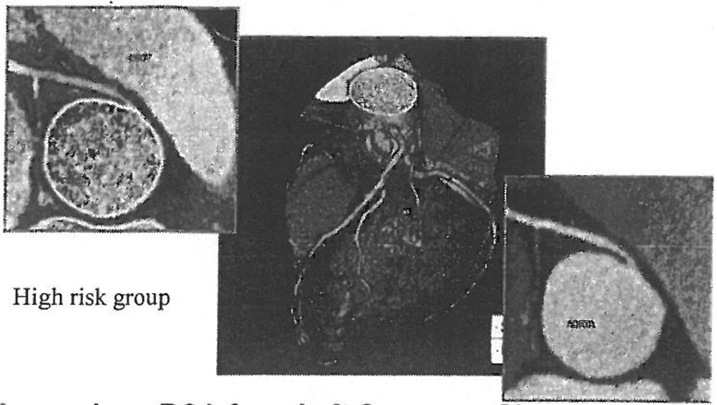
Cardiac CT





Hypertrophic Cardiomyopathy

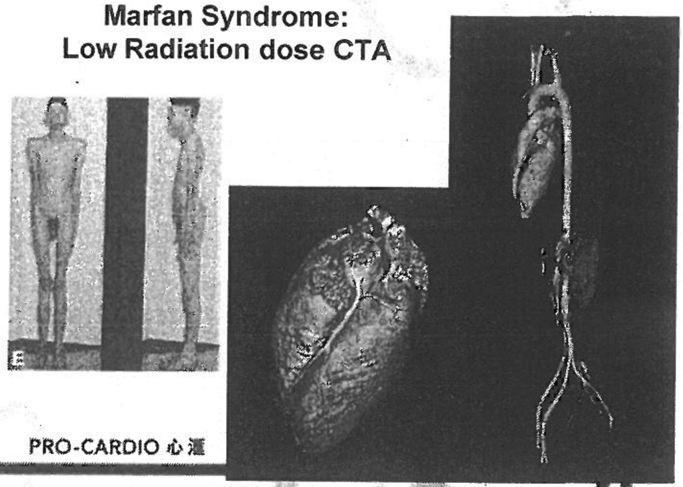
CCTA a Golden Standard for Diagnosis of Anomalous CA



High risk group

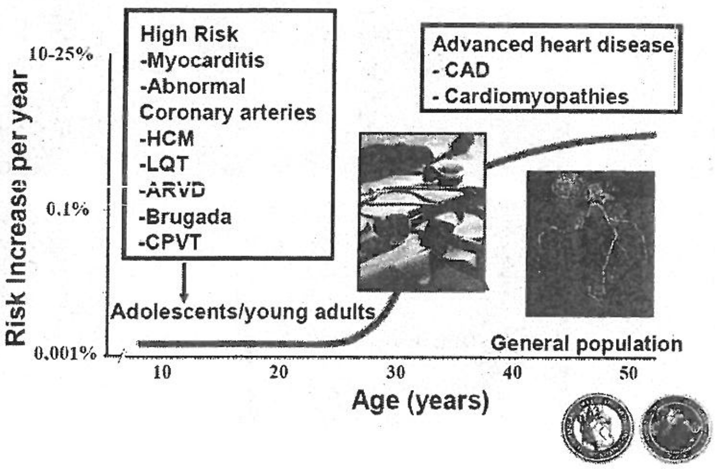
Anomalous RCA from Left Coronary Sinus

Marfan Syndrome: Low Radiation dose CTA



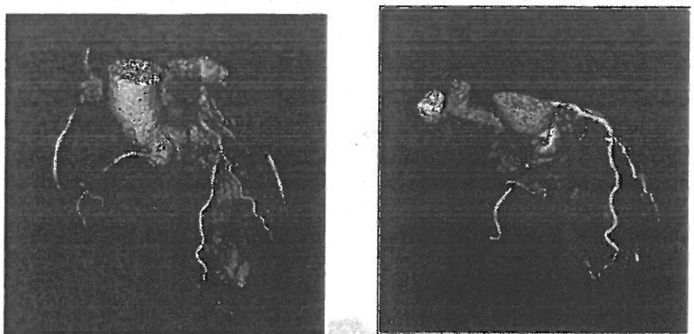
PRO-CARDIO 心滙

Age-specific risk and causes

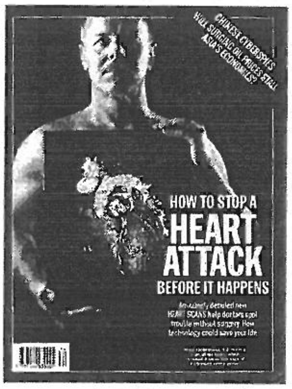


PRO-CARDIO 心滙

M/45 Asian Para Game Badminton Player, severe HT, severe LVH, asymtomatic



PRO-CARDIO 心滙



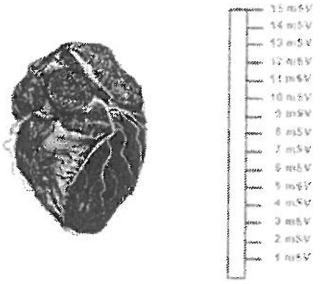
2005

Problems of 64 slices CT:
- Low resolution
- Require Slow HR (< 65 bpm)
- Tachycardia / AF impossible
- High radiation dose

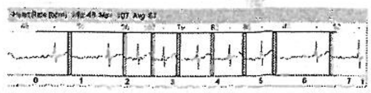
PRO-CARDIO 心滙

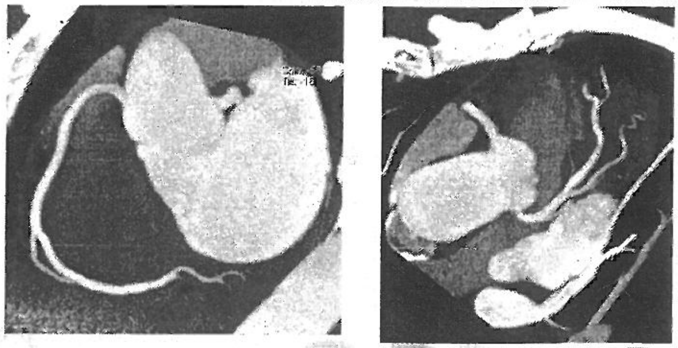
輻射劑量
只是每人每年接受天然輻射的三分一

新一代
雙源CT掃描系統
Dual Source
CT 2X128

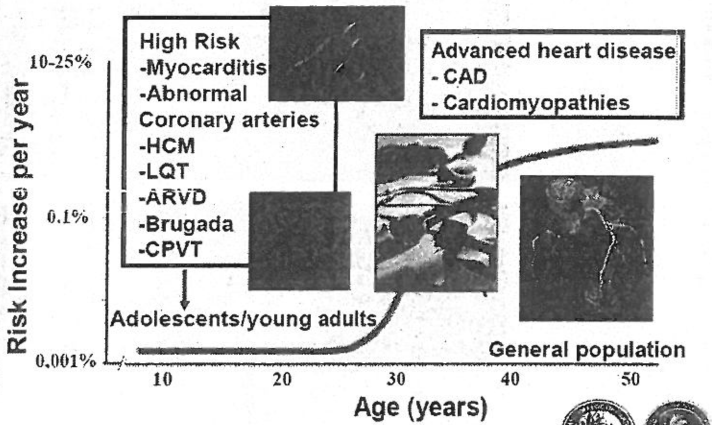


AF is common in Endurance Athletes





Age-specific risk and causes



Who Might Benefit From Low Radiation CCTA?

- Patients with symptoms:
  - Chest pain / tightness, breathless, palpitation or syncope
- Asymptomatic intermediate to high risk individuals:
  - men>45, women >55
  - Strong family History of premature CAD
  - Diabetic or other major risk factors
  - established disease: CAD, CVA or PVD
  - Pre-participation screening for vigorous competitive sports

Conclusion I

- **Endurance training produce sustained CV effects including eccentric LV hypertrophy and increased Vagal tone.**
- **A slow resting heart rate and Atrial Fibrillation (5X) are common. Right heart dysfunction, heart muscle injury and fibrosis has been documented especially in the ultra-endurance athletes such as marathon runners.**
- **Exercise related Sudden Cardiac Arrest (SCA) are usually related to congenital or structural abnormalities in younger than 35 and coronary artery disease in those 35 years and above.**

Conclusion 2

- **The combination of carefully conducted history and examination (according to the 12-element AHA recommendations) and 12-lead resting ECG are generally effective screening protocols.**
- **The additional use of echocardiograms in the younger athletes (<35 years of age) and the low radiation dose Coronary CT Angiography in the old athletes (>35 years of age) are high sensitive and specific in identify those at risk and potentially prevention of exercise related sudden cardiac arrest.(SCA) .**