Your heart on exercise

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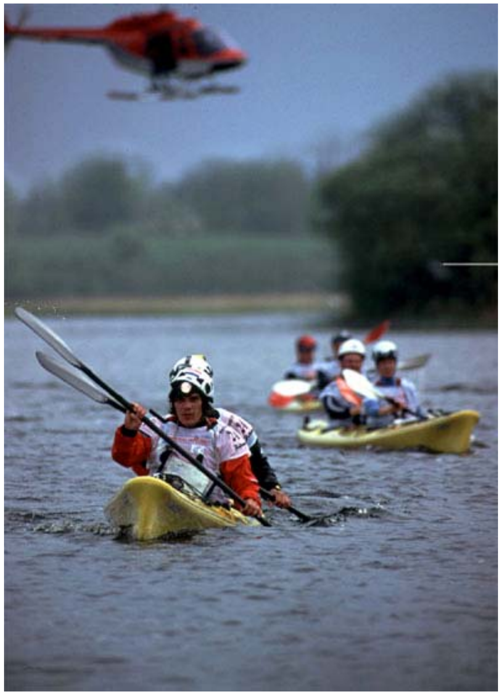
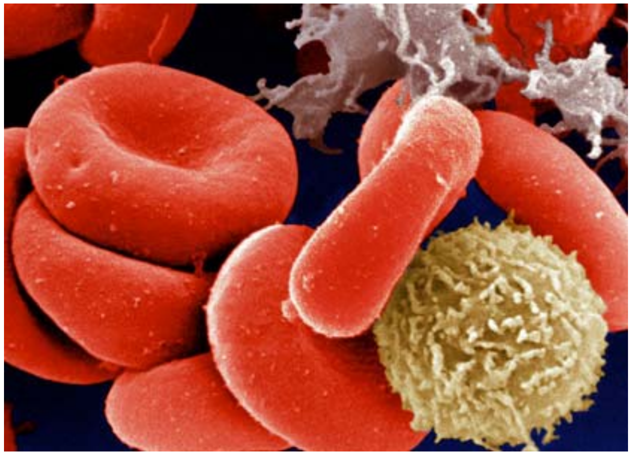
Outline

- The cardiovascular system
- Exercise and the heart
- The athlete's heart
- Health benefits of exercise



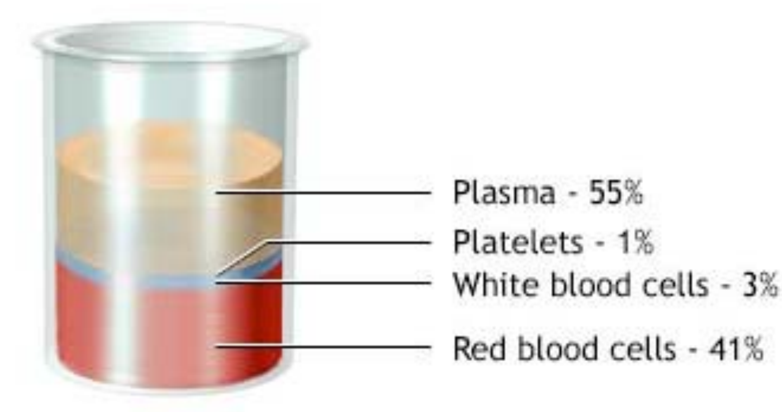
The cardiovascular system

- Function
  - To deliver oxygen & nutrients
  - To remove waste (carbon dioxide)
- Distributed immune / thermoregulatory system
- Pump, blood, blood vessels



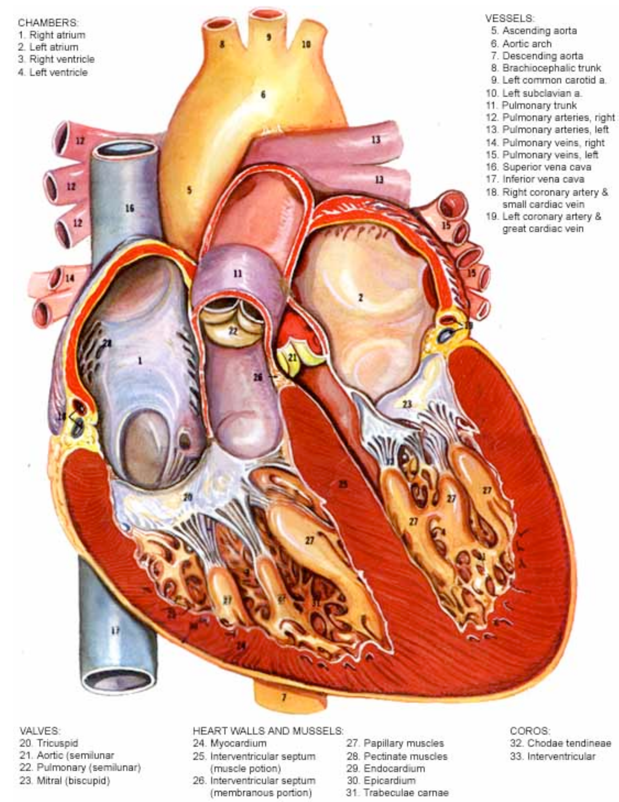
Blood

- Blood
  - Red cells (40%)
  - White cells/platelets (5%)
  - Plasma (55%)
- Flows from heart to major arteries then capillaries
- Returns to heart via veins



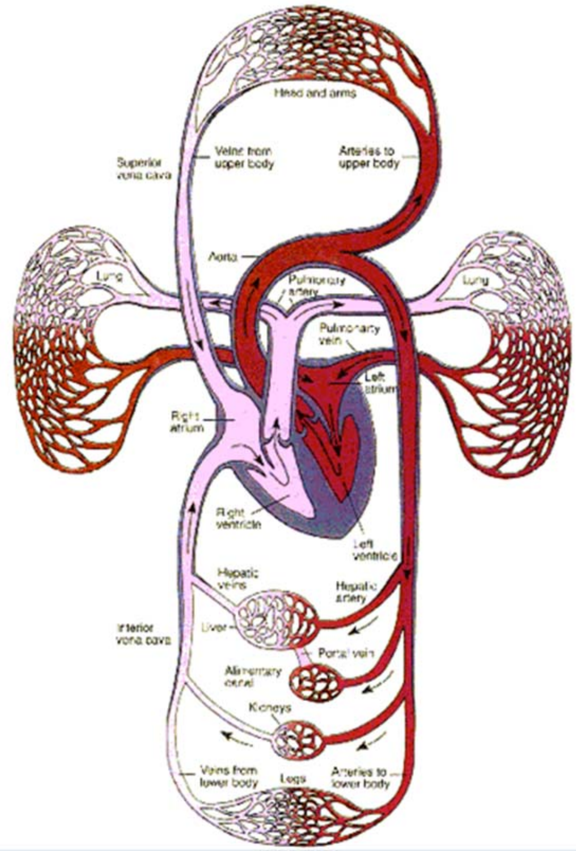
The heart

- Pump
  - 4 chambers
  - 4 valves
  - 10 leaflets
  - 5 papillary muscles
- Fuel supply
  - Coronary arteries
- Electrical system
  - Specialized conducting tissue



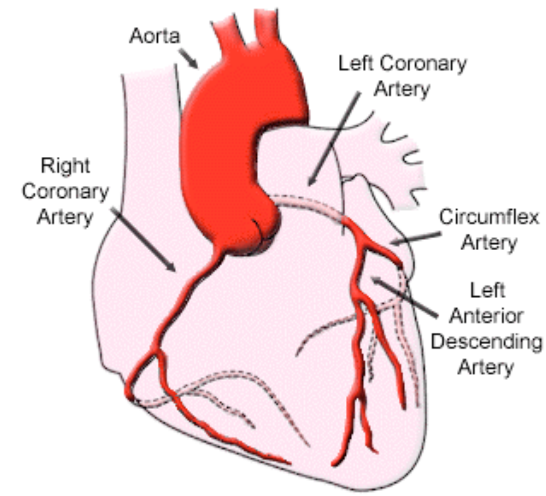
Pump

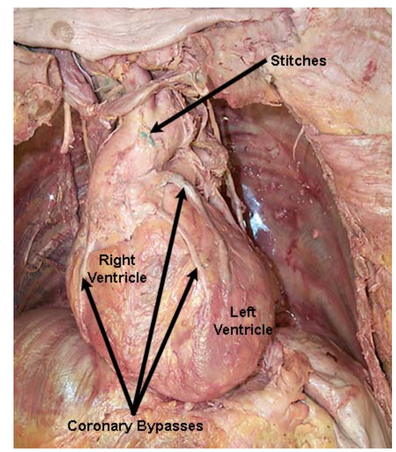
- Circulation
  - Blood is oxygenated in the lungs
  - Delivered to heart
  - Pumped to body
  - Returned to heart
  - Delivered to lungs



Fuel supply – coronary arteries

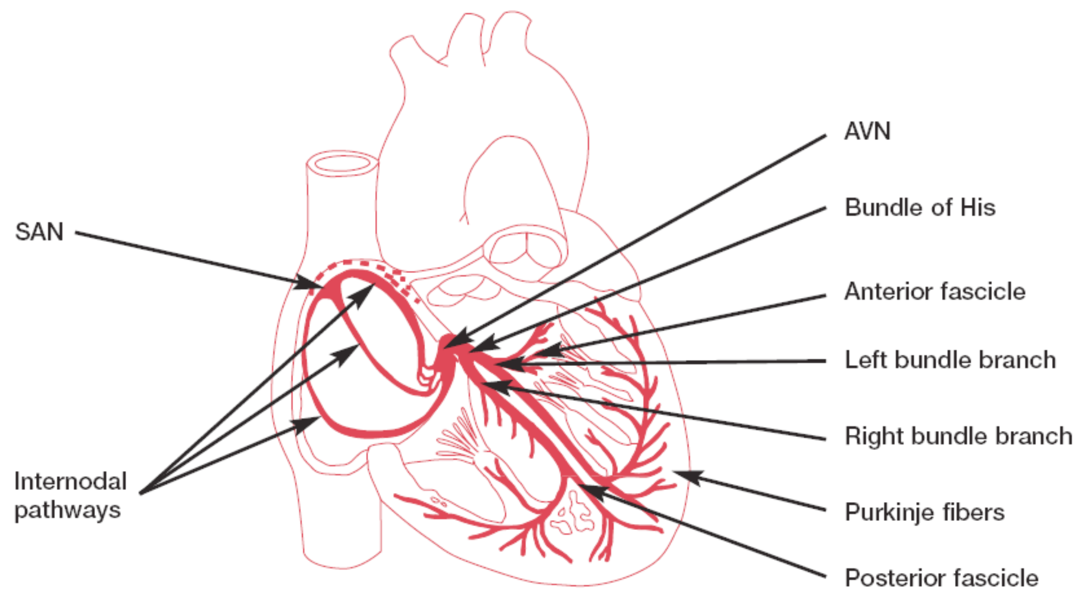
- 3 principal arteries
- Multiple small branches
- The first arteries to come off the aorta
  - Heart supplies itself first

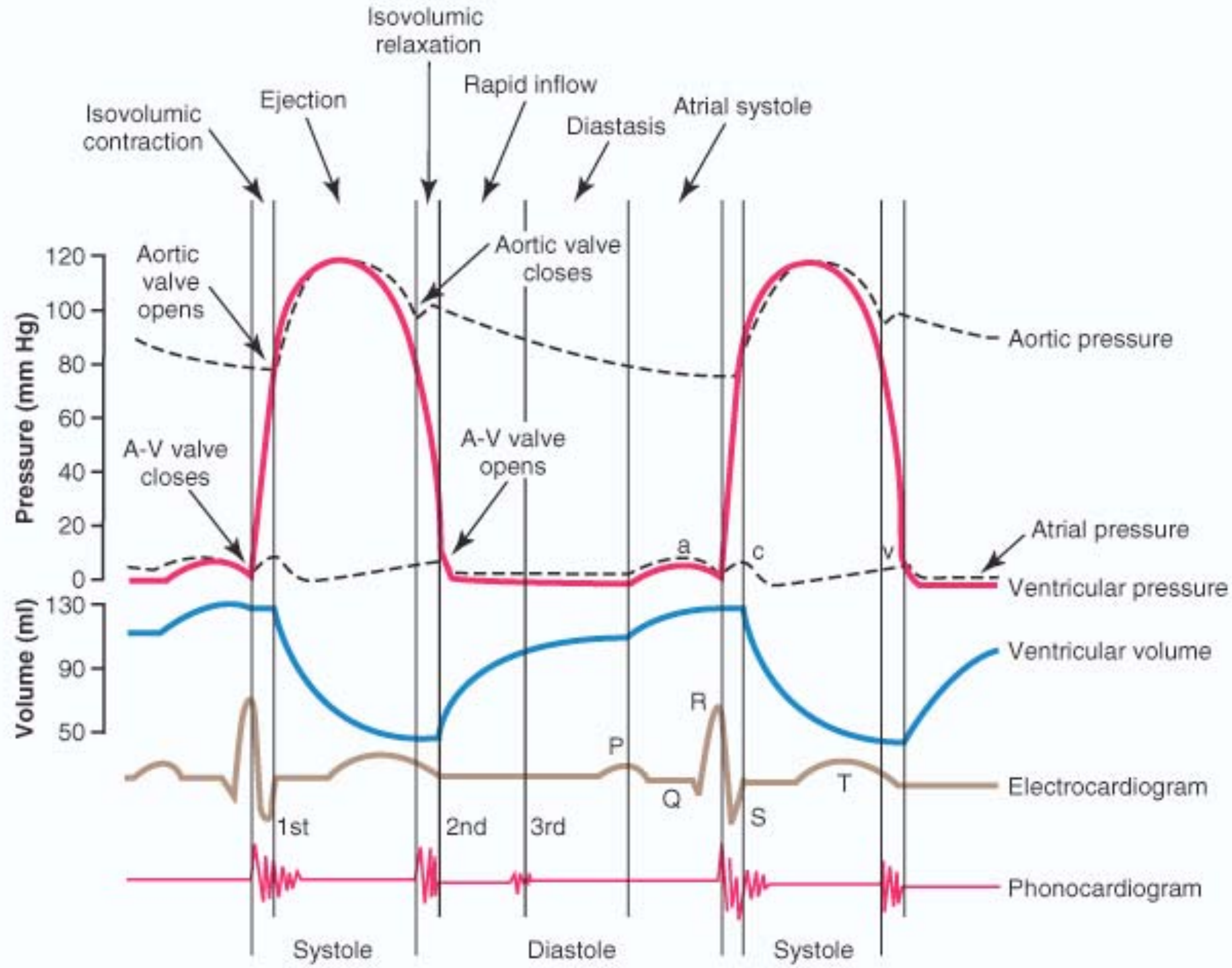




Electrical system

- All heart cells conduct electrically
- Specialized conduction tissue conducts faster and takes priority
- All cells are capable of being "pacemakers"
- Cells high up in right atrium pace faster and override other cells




Isovolumic relaxation
Rapid inflow
Ejection
Isovolumic contraction
Diastasis
Atrial systole
Aortic valve opens
Aortic valve closes
Aortic pressure
Pressure (mm Hg)
120
100
80
60
40
20
0
A-V valve closes
A-V valve opens
Atrial pressure
a
c
v
Ventricular pressure
Volume (ml)
130
90
50
Ventricular volume
R
P
Q
S
T
Electrocardiogram
1st
2nd
3rd
Phonocardiogram
Systole
Diastole
Systole

Exercise

Cardiology

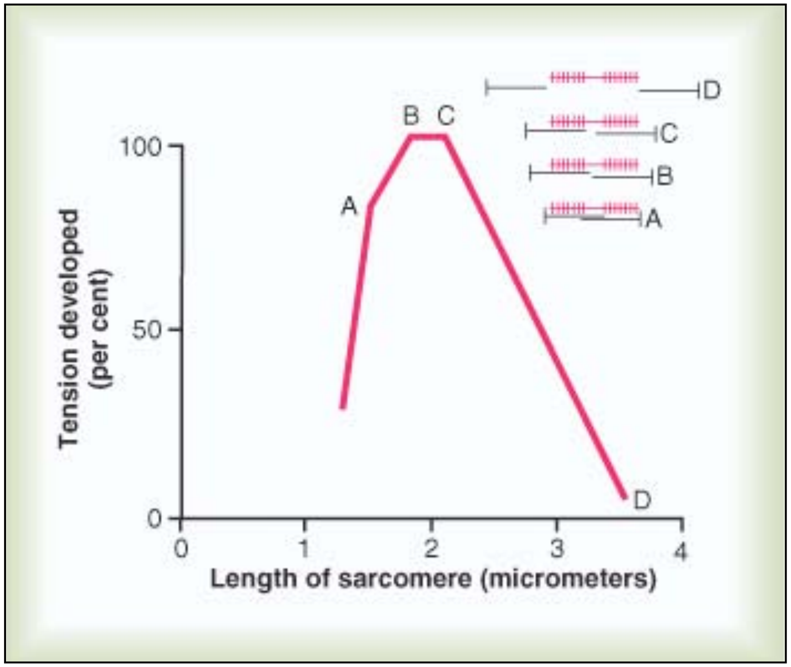
BOSTON MARATHON
WELCOME TO HOPKINTON
IT ALL STARTS HERE
HOPKINTON TO BOSTON: 26 MILES — 385 YARDS
HOPKINTON MARATHON COMMITTEE 1979

Heart rate

- Exercise control begins in the brainstem before exercise begins
- Heart rate
  - Increases linearly with work rate
  - Under control of internal nervous systems
    - withdrawal of vagal tone
    - increased adrenaline
  - 25 to 240 bpm
  - 220-age but SD approx 10
  - Cardiac ‘drift’ with prolonged exercise

Stroke volume

- Increased volume of heart
- Increased cardiac output per beat
  - rest 50ml
  - untrained ↑ 120ml
  - trained >200ml
- Atrial filling becomes more important



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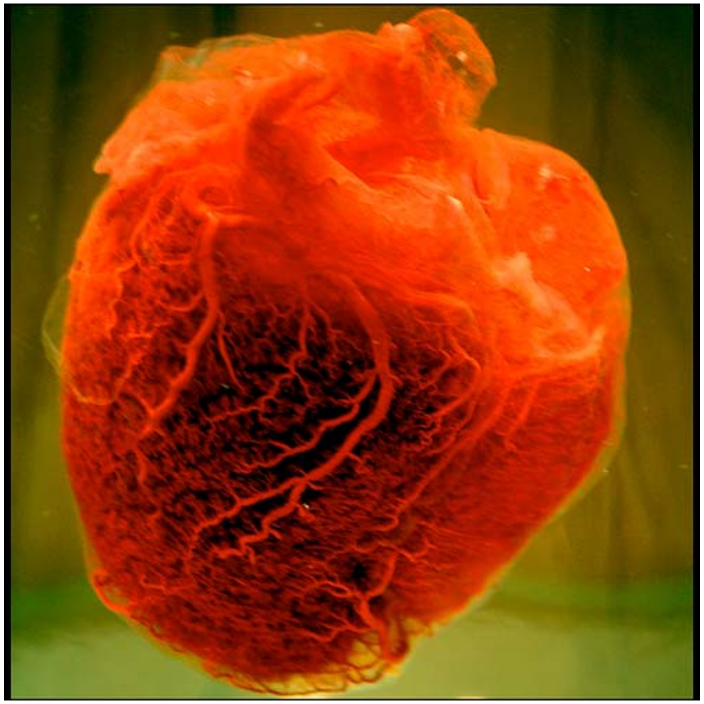
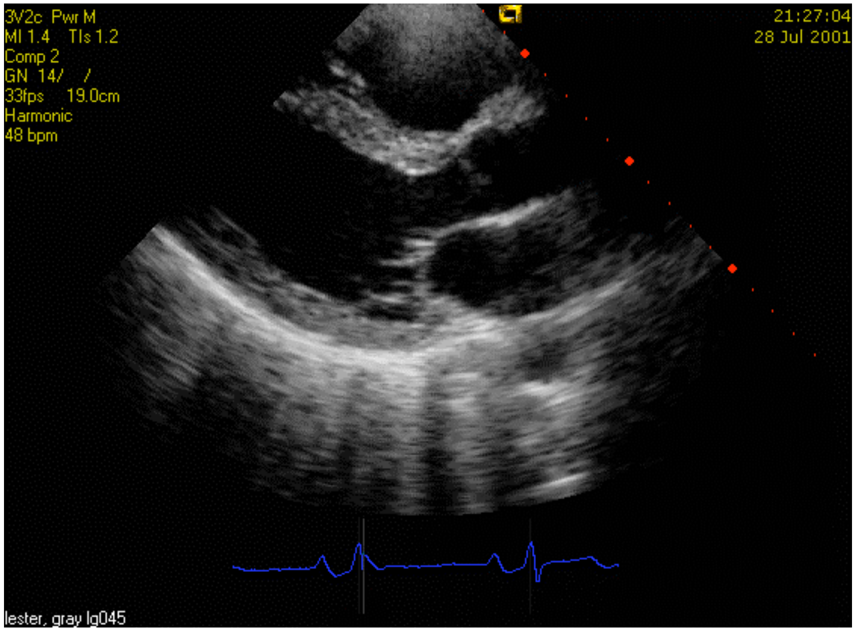
Role of blood vessels

- Increased preload
  - muscle pump
  - respiratory pump
- Increased SBP
- Minor increase DBP
- Redistribution
  - Skeletal muscle vasodilation
    - 20% → 80% of cardiac output
  - GI vasoconstriction

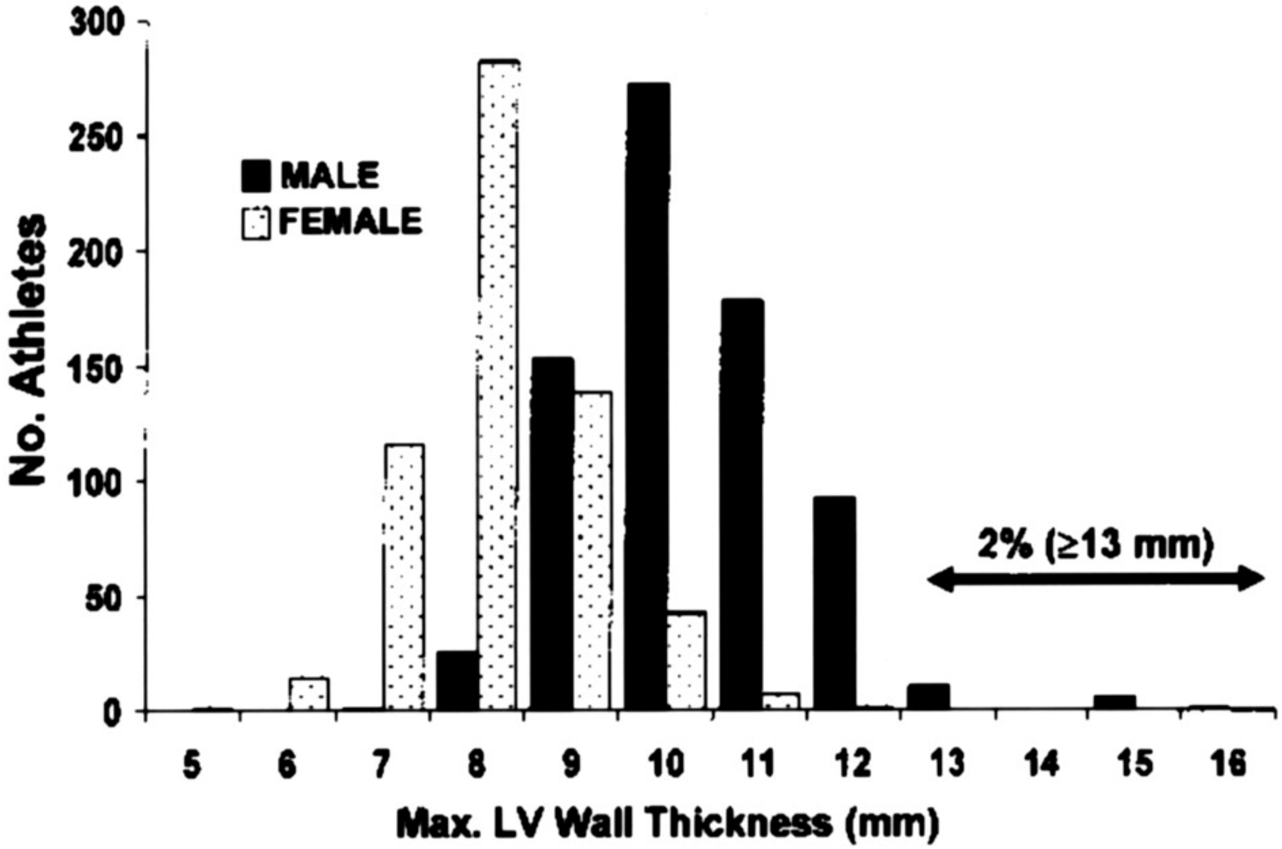


Human heart clarified and injected with cinnabar to display blood vessels (Mütter Museum, College of Physicians of Philadelphia)

Athlete’s heart



The Athlete's heart



J Am Coll Cardiol. 2004;44:1053–1058.

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The athlete's heart

Comparative Left Ventricular Dimensions in Trained Athletes

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Little is known about the structure of athletes' hearts or anatomic variations associated with training. Echocardiograms of 56 active athletes were obtained. Mean left ventricular end-diastolic volume and mass were increased in athletes involved in isotonic exercise, such as swimming (181 ml, 308 g) and running (160 ml, 302 g), compared with controls (101 ml, 211 g); wall thickness was normal (≤ 12 mm). Athletes involved in isometric exercise, such as wrestling and shot putting, had normal mean left ventricular end-diastolic volumes (110 ml, 122 ml), but increased wall thickness (13 to 14 mm) and mass (330 g, 348 g). Thus, athletes participating in isotonic exercise had increased left ventricular mass with cardiac changes similar to those in chronic volume overloads. Athletes participating in isometric exercise had increased left ventricular mass with cardiac changes similar to those in chronic pressure loads. Recognizing greater left ventricular mass and volume in well-trained athletes aids in interpreting values deviating from "normal" limits.

TRAINED ATHLETES often have abnormal electrocardiograms (ECGs), radiographic evidence of cardiac enlargement, and systolic murmurs, findings that have been referred to as the "athlete's heart syndrome" (1). In addition, it would appear that while athletes participating in isotonic or endurance events usually have radiographic evidence of cardiac enlargement, athletes involved in isometric or strength training usually show peripheral muscular hypertrophy without an obvious increase in cardiac size (2-4). Aside from these radiographic observations, however, no other information is available relative to the gross morphologic characteristics of the hearts of athletes, or to the anatomic variations associated with different kinds of physical conditioning. Undoubtedly, this has been due largely to the lack of a noninvasive technique that can provide a more sophisticated analysis of cardiac anatomy than simple chest roentgenography affords. In recent years, however, echocardiography has provided a noninvasive and sensitive means for assessing, among other things, ventricular cavity size and myocardial wall dimensions. We therefore employed echocardiography to study the hearts of trained athletes to ascertain whether athletes have an increased left ventricular mass, and, if so, whether athletes participating in different events have different patterns of hypertrophy and enlargement.

► From the Cardiology Branch, National Heart and Lung Institute, National Institutes of Health, Bethesda, Maryland.

Patient Selection

Forty-two actively competing male college varsity athletes from the University of Maryland (15 swimmers, 15 long-distance runners, and 12 wrestlers) were studied during their competitive season. Their ages ranged from 18 to 24 years, and 97% were Caucasian. All athletes had participated in their athletic event for more than 3 years and trained actively more than 200 days per year. Sixteen age- and sex-matched students who did not normally compete in athletics were selected from the same university and served as a normal control population. No subject was known to be on any pharmacological agent. All of the college athletes checked their resting heart rate for one complete minute daily for several days prior to study; these values were averaged and the mean resting heart rate was recorded. In addition, 10 long-distance runners and 4 shot putters of world class caliber (International Track Association, Los Angeles, California) were studied. The acknowledged world record holders in each of these two events were among those studied.

Data Collection

A medical history, physical examination, and a standard 12-lead electrocardiogram were obtained at rest for all subjects. Echocardiograms were obtained during resting conditions with an Aerotech gamma transducer (Aerotech Laboratories, Division of Branson Instrument Co., Lewistown, Pennsylvania) and a modified Ekoline 20A ultrasonic unit (Smith Kline Instrument Co., Philadelphia, Pennsylvania). The signal was connected via a custom-built video amplifier to a Honeywell 1856 visicorder (Honeywell Co., Denver, Colorado) and recorded continuously on light-sensitive paper. The T-scan technique (5) was used to visualize the ventricular septum and the posterobasal left ventricular wall. The ventricular septum was measured inferior to the distal margins of the mitral leaflets just before atrial systole. Posterobasal left ventricular free wall thickness was measured at the same time in the cardiac cycle with the transducer oriented so that part of the ultrasonic beam was reflected from the posterior mitral leaflet. Left ventricular end-diastolic volume was estimated from left ventricular internal dimension at end diastole using a previously described method (6). Left ventricular mass was calculated from the echocardiographic measurements by the method of Troy, Pombo, and Rackley (7).

Results

GENERAL INFORMATION

No subject in this study had a history of a serious medical condition. The only symptom identifiable in the college athletes was intermittent dizziness, experienced either after extreme exertion or with sudden postural changes. None considered this anything but a casual and infrequent symptom. Dizziness was reported in 4 of 15

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Strength trained athletes do not have more or different athletic hypertrophy than endurance trained athletes

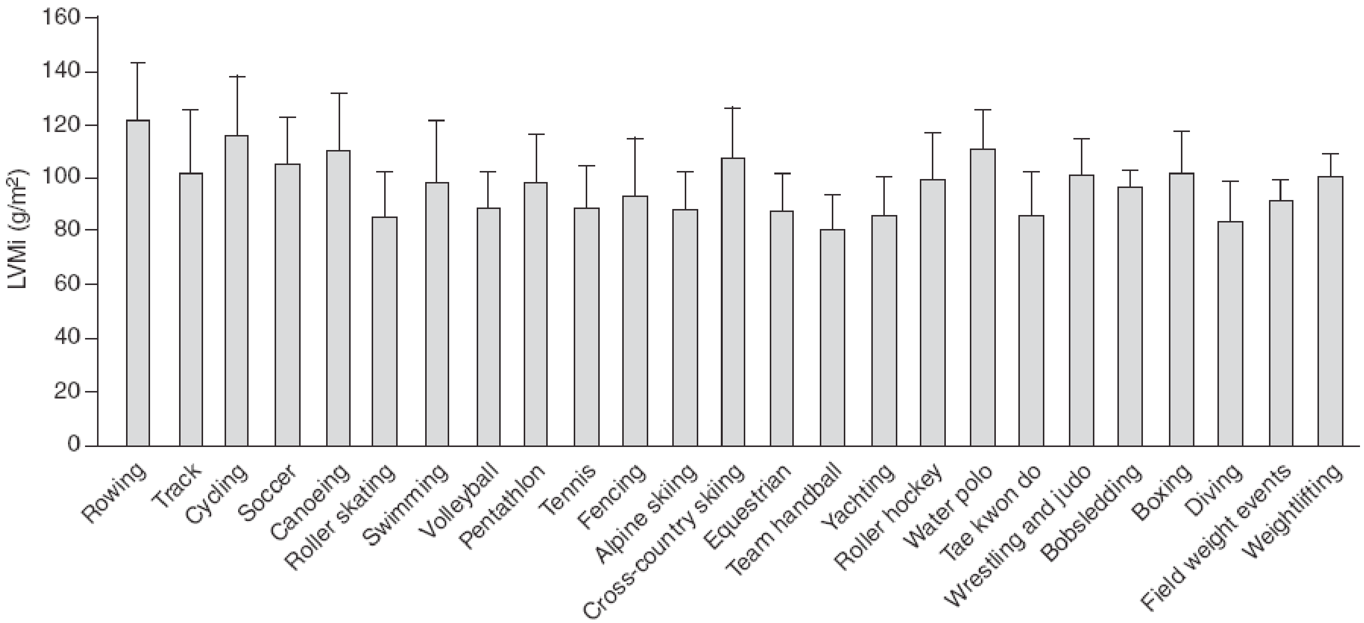

Fig. 1. Mean left ventricular mass indexed to body surface area (LVMi) in 947 elite Italian athletes divided according to sporting events.[18]

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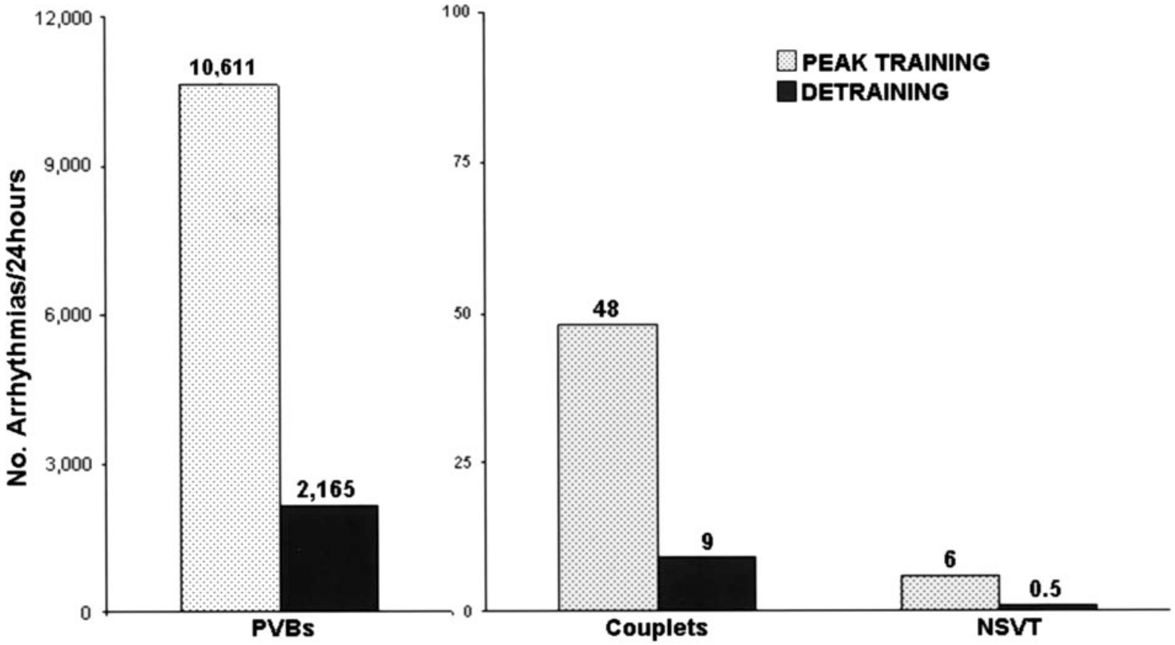
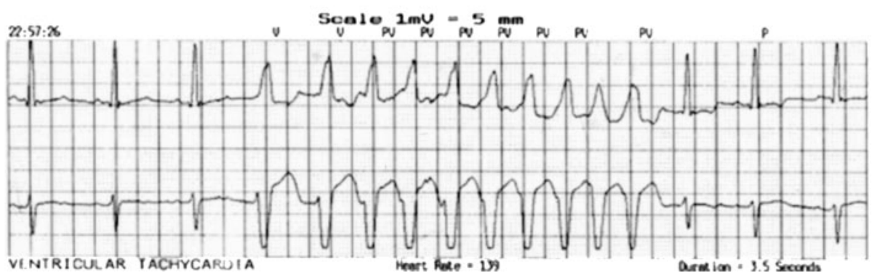
Extra beats are common





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Athlete's heart - summary

- Slower resting heart rate
- Slower heart rate at given workload
- No change in maximal heart rate
- More elastic heart muscle
- Slightly bigger heart cavity
- Mild or no change in heart wall thickness
- Some extra beats normal

Health benefits of exercise

Cardiovascular benefits of exercise

- Longer life
- Decreased risk of heart attack
- Decreased risk of stroke
- Reduced obesity
- Reduced diabetes
- Improved cholesterol
- Reduced blood pressure
- Improved endothelial function
- Improved varicose veins

Neurological benefits of exercise

- Decreased risk of stroke
- Improved mood
- Better cognitive function (older adults)
- Reduced stress
- Enhanced sleep
- Improved agility
- Enhanced coordination and balance

Benefits of exercise for bone, joint and muscle

- Reduced obesity
- Improved agility
- Improved endurance
- Improved posture
- Less back pain
- Increased bone density
- Reduced inflammation
- Improved muscle metabolism

Anti-cancer benefits of exercise

- Decreased risk of breast cancer
- Decreased risk of colon cancer
- Decreased risk of pancreatic cancer

More benefits of exercise

- Enhanced immune system
- Reduced risk of glaucoma
- Reduced inflammation
- Improved appetite for healthy foods
- Reduced risk of gall stones
- Reduced diverticulitis

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There must be a downside to all this goodness?

The exercise paradox

- There is risk associated with exercise
- Risk-protection paradox
- Risk extraordinarily low in absolute terms
  - 1:500,000 to 2.5m hours of exercise
- However, exercise can trigger heart events
- Notably, regular exercise lessens multiplicative risk dramatically
  - In rare exercisers, increase in risk with exercise is 50x that of regular exercisers
  - In common exercisers, < 2x
- Key message: benefit outweighs risk by orders of magnitude
- Regular exercise reduces risk of CV events by 50%

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What about sudden death in young athletes?

Ryan Shay
marathon
Hypertrophic cardiomyopathy (HCM)

Scott Laio
rowing
unknown

Hank Gathers
basketball
HCM

Jiri Fischer
hockey
HCM, survived

Jason Collier
basketball
HCM

Marc Vivien Foé
soccer
HCM

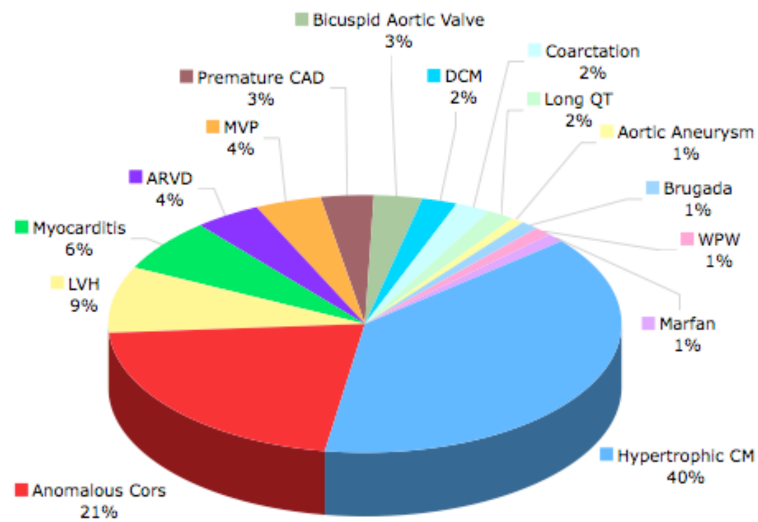
Antonio Puerta
soccer
ARVC

Thomas Herrion
football
HCM

Amy Marie Moxie
swimming
Aortic Dissection

Causes of SCD in young athletes

- Sudden death is very rare in young athletes
- The most common cause is hypertrophic cardiomyopathy
  - a genetic disease of heart muscle
- Screening may be able to reduce the risk of events in athletes (young and old)



Matthew Wheeler

ECG screening of Stanford athletes

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Conclusion

Exercise is good for you

Exercise is good for your heart

Physician heal thyself…