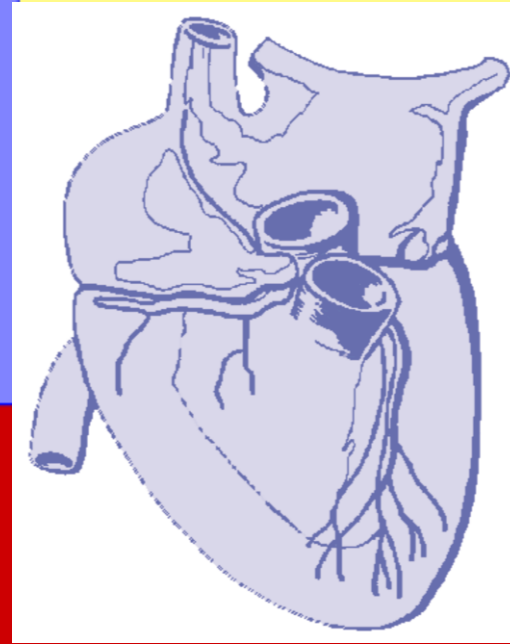




# CARDIOVASCULAR CONTROL DURING EXERCISE



# Major Cardiovascular Functions

- ◆ Delivery (e.g., oxygen and nutrients)
- ◆ Removal (e.g., carbon dioxide and waste products)
- ◆ Transportation (e.g., hormones)
- ◆ Maintenance (e.g., body temperature, pH)
- ◆ Prevention (e.g., infection—immune function)

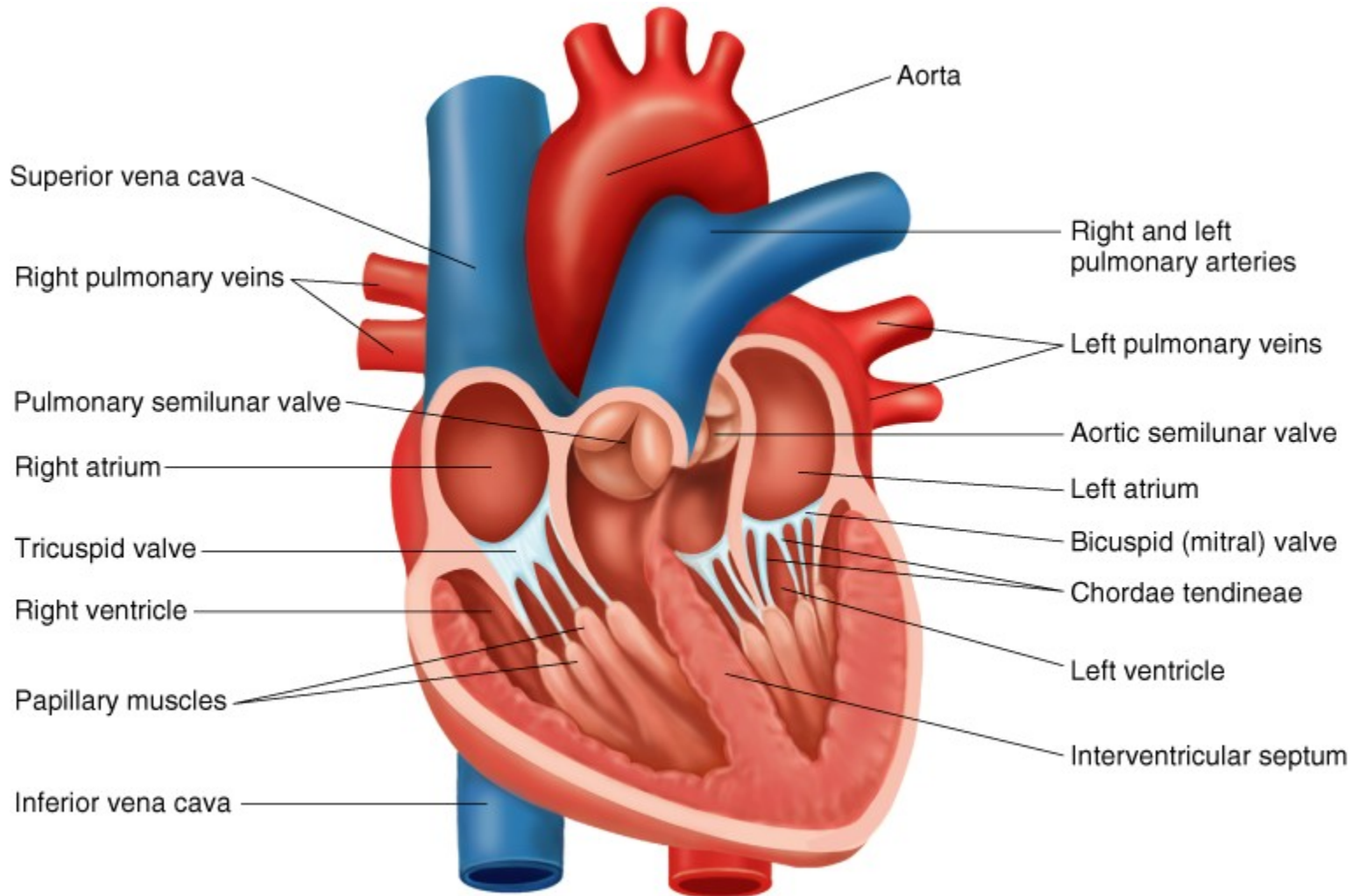


# Cardiovascular System

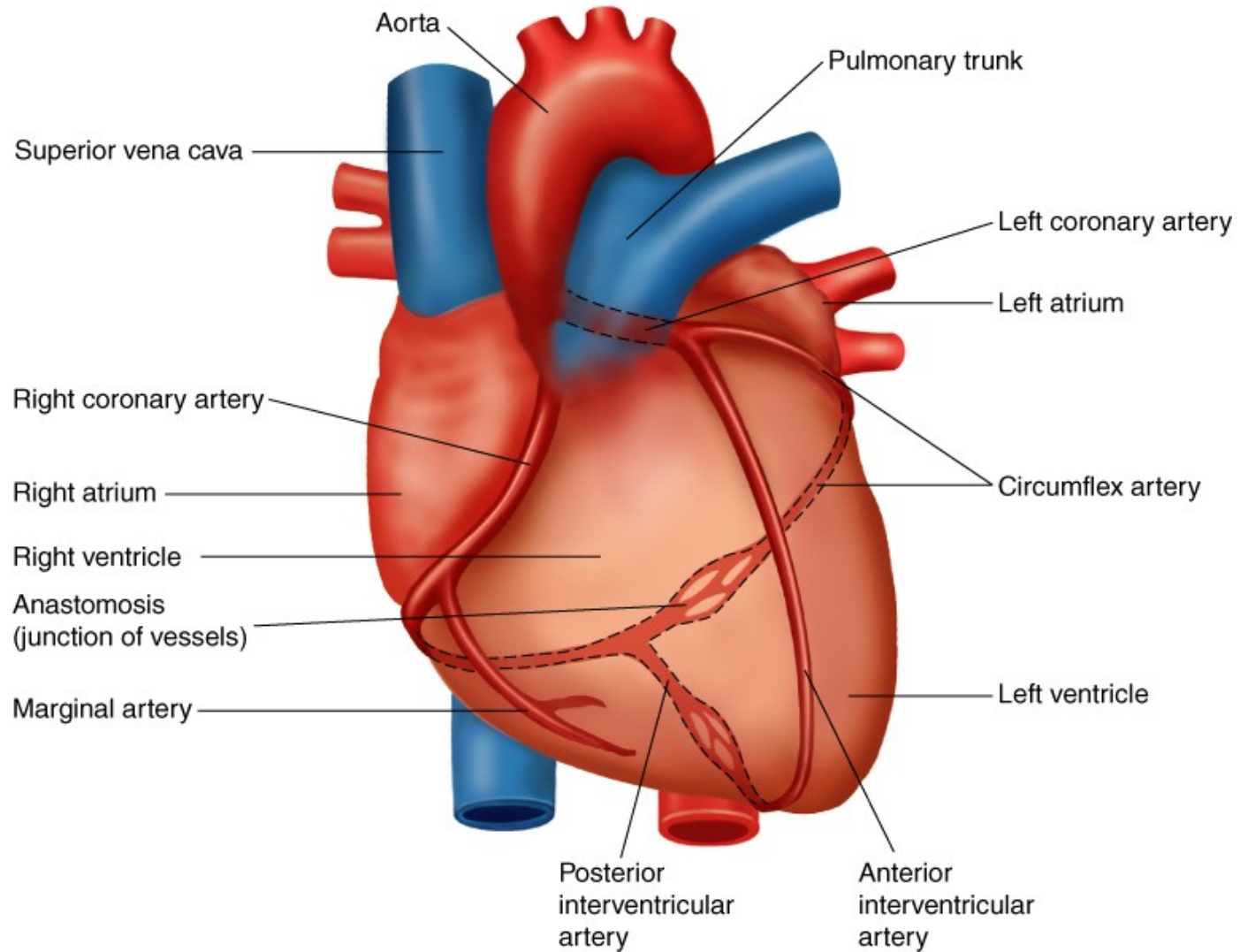
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- ◆ A pump (the heart)
- ◆ A system of channels (the blood vessels)
- ◆ A fluid medium (blood)

# HEART



# CORONARY CIRCULATION



# Key Points

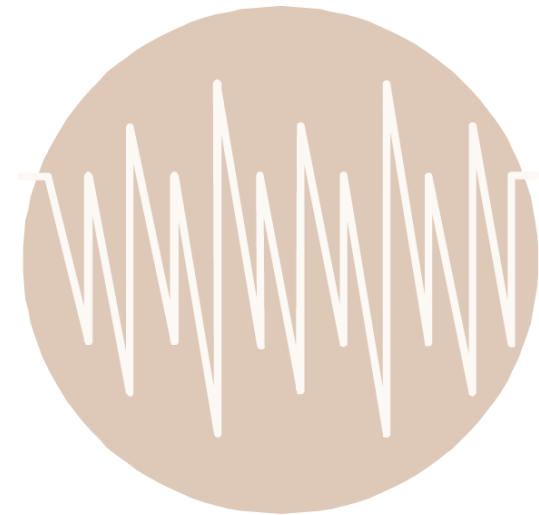
## Structure and Function of the Cardiovascular System

- ◆ The two atria receive blood into the heart; the two ventricles send blood from the heart to the rest of the body.
- ◆ The left ventricle has a thicker myocardium due to hypertrophy resulting from the resistance against which it must contract.

# Did You Know...?

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Resting heart rates in adults tend to be between 60 and 85 beats/min. However, extended endurance training can lower resting heart rate to 35 beats/min or less. This lower heart rate is thought to be due to decreased intrinsic heart rate and increased parasympathetic stimulation.



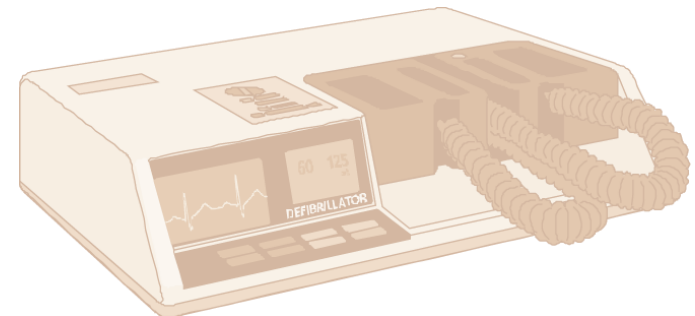
# Cardiac Arrhythmias

**Bradycardia**—resting heart rate below 60 beats/min

**Tachycardia**—resting heart rate above 100 beats/min

**Premature ventricular contractions (PVCs)**—feel like skipped or extra beats

**Ventricular tachycardia**—three or more consecutive PVCs that can lead to ventricular fibrillation in which contraction of the ventricular tissue is uncoordinated





# Cardiac Cycle

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- ◆ Events that occur between two consecutive heartbeats (systole to systole)
- ◆ Diastole—relaxation phase during which the chambers fill with blood - 62% of cycle duration
- ◆ Systole—contraction phase during which the chambers expel blood - 38% of cycle duration

# Stroke Volume and Cardiac Output

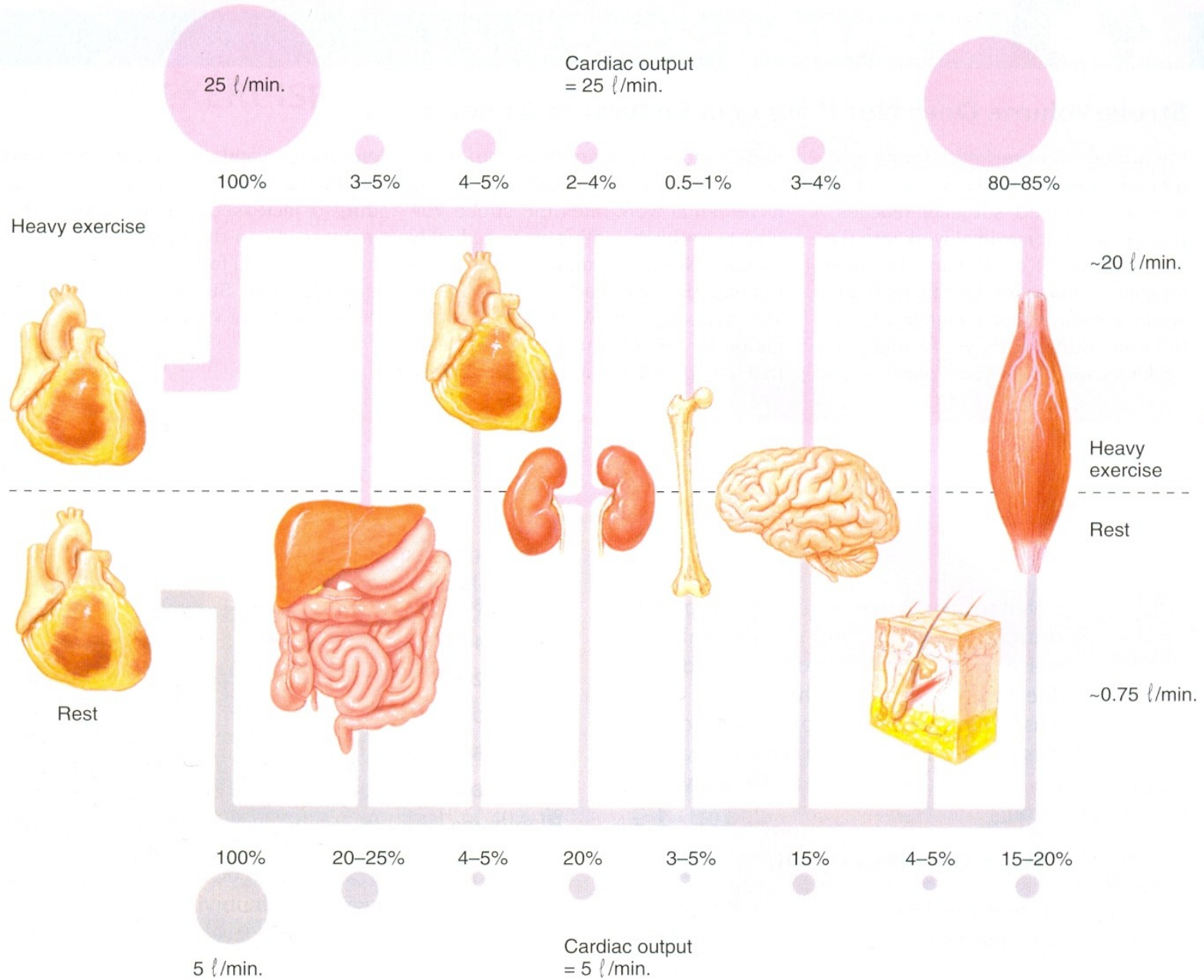
## Stroke Volume (SV)

- ◆ Volume of blood pumped per contraction
- ◆ End-diastolic volume (EDV)—volume of blood in ventricle before contraction
- ◆ End-systolic volume (ESV)—volume of blood in ventricle after contraction
- ◆  $SV = EDV - ESV$

## Cardiac Output ( $\dot{Q}$ )

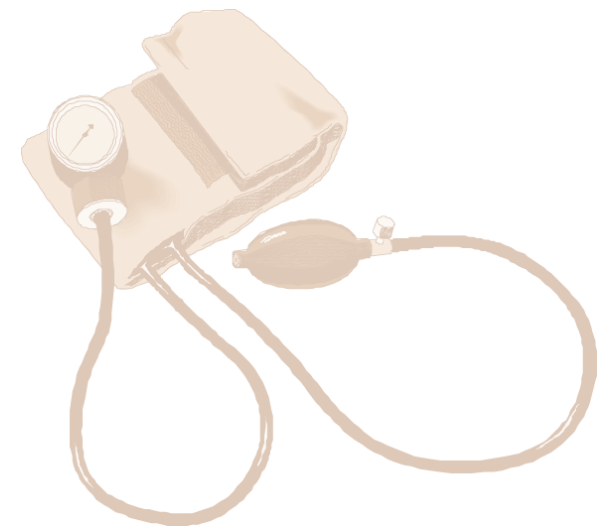
- ◆ Total volume of blood pumped by the ventricle per minute
- ◆  $\dot{Q} = HR \times SV$

# BLOOD DISTRIBUTION



# Blood Pressure

- ◆ Systolic blood pressure (SBP) is the highest pressure and diastolic blood pressure (DBP) is the lowest pressure
- ◆ Mean arterial pressure (MAP)—average pressure exerted by the blood as it travels through arteries
- ◆  $MAP = DBP + [0.333 \times (SBP - DBP)]$
- ◆ Rest Blood Pressure is about 120/80
- ◆ Hypertension: BP = more than 140/90
- ◆ Hypotension: BP = less than 90/60



# Parameters Affected by Training

- ◆ Heart size
- ◆ Stroke volume
- ◆ Heart rate
- ◆ Cardiac output
- ◆ Blood flow
- ◆ Blood pressure
- ◆ Blood volume



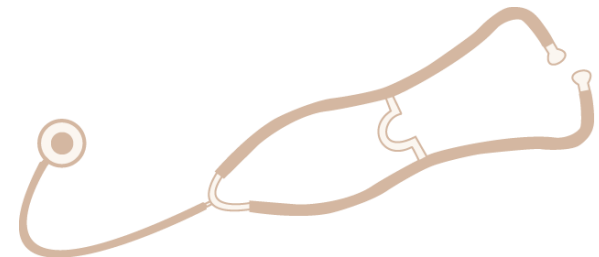
# Cardiovascular Response to Acute Exercise

- ◆ Heart rate (HR) increases as exercise intensity increases up to maximal heart rate.
- ◆ Stroke volume (SV) increases up to 40% to 60%  $\dot{V}O_2$ max in untrained individuals and up to maximal levels in trained individuals.
- ◆ Increases in HR and SV during exercise cause cardiac output ( $\dot{Q}$ ) to increase.
- ◆ Blood flow and blood pressure change.
- ◆ All result in allowing the body to efficiently meet the increased demands placed on it.



# Resting Heart Rate

- ◆ Averages 60 to 80 beats/min; can range from 28 to above 100 beats/min
- ◆ Tends to decrease with age and with increased cardiovascular fitness
- ◆ Is affected by environmental conditions such as altitude and temperature



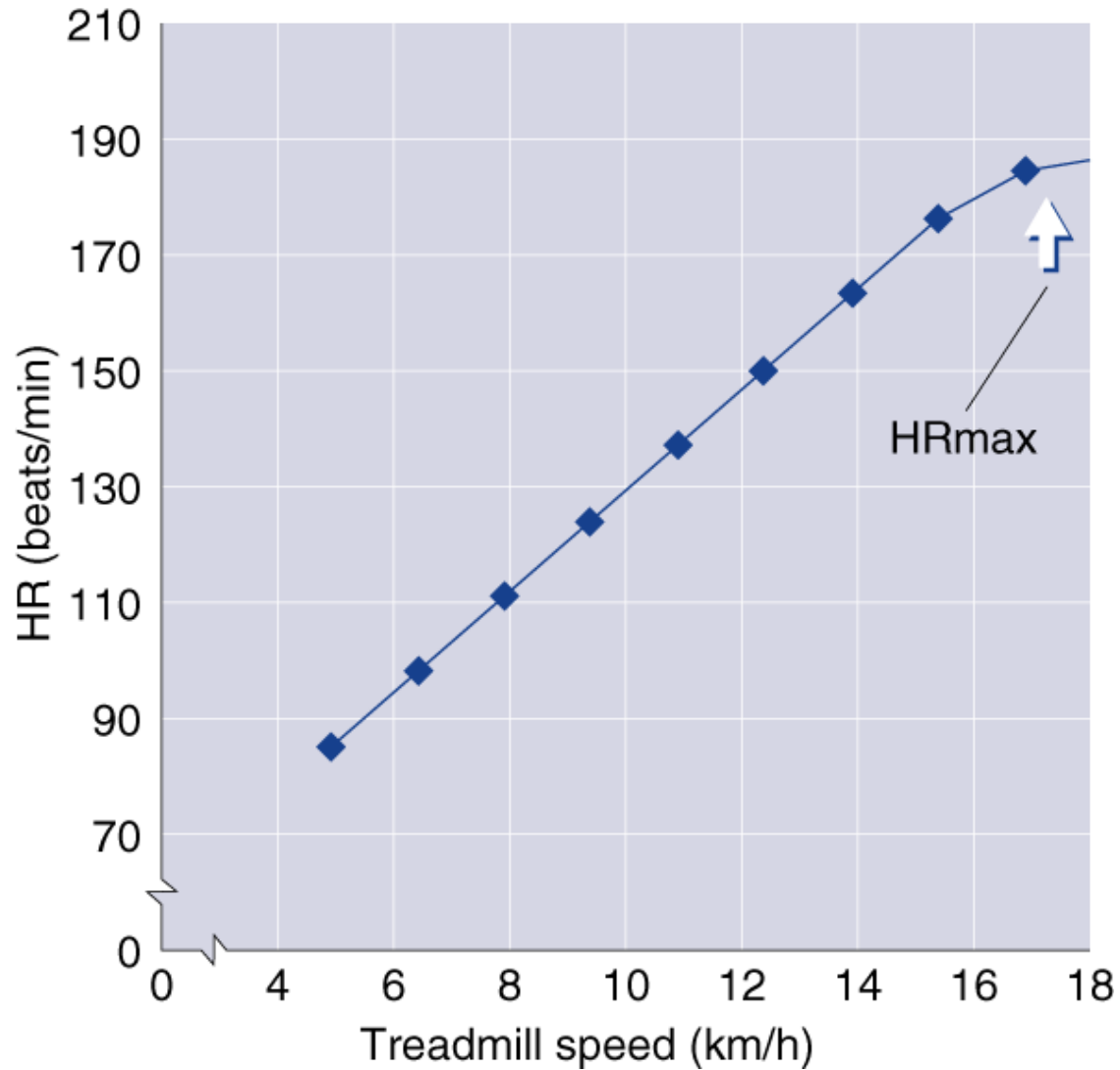
# Maximum Heart Rate

- ◆ The highest heart rate value one can achieve in an all-out effort to the point of exhaustion
- ◆ Remains constant day to day and changes slightly from year to year
- ◆ Can be *estimated*:  $HR_{max} = 220 - \text{age in years}$  or  $HR_{max} = 208 - (0.7 \times \text{age})$

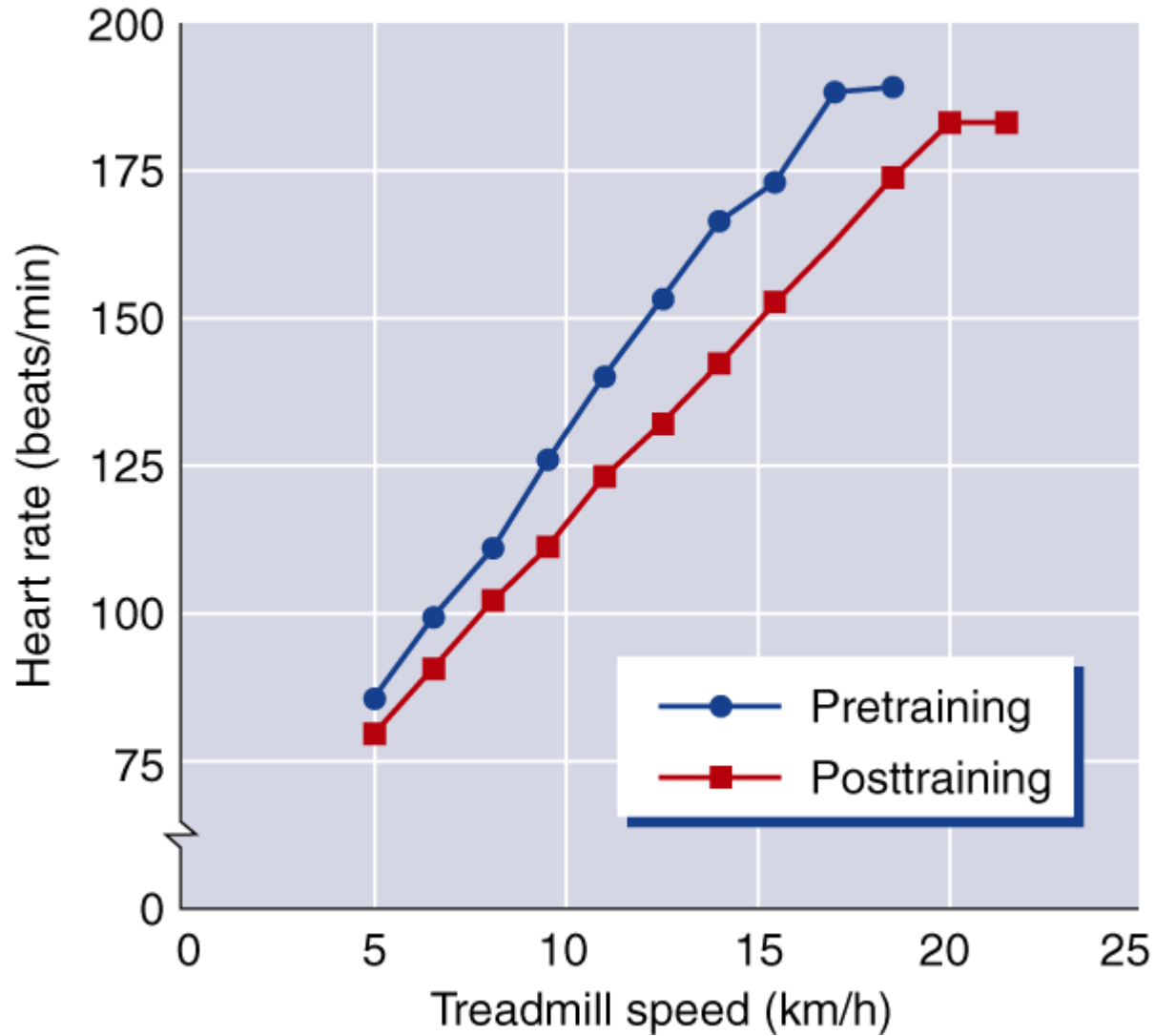




# HEART RATE AND INTENSITY



# HEART RATE AND TRAINING



# Resting Heart Rate

- ◆ Decreases with endurance training likely due to more blood returning to heart and changes in autonomic control
- ◆ Sedentary individuals can decrease RHR by 1 beat/min per week during initial training, but several recent studies have shown small changes of less than 3 beats/min with up to 20 wk of training
- ◆ Highly trained endurance athletes may have resting heart rates of 30 to 40 beats/min



# Heart Rate During Exercise

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## Submaximal

- ◆ Decreases proportionately with the amount of training completed
- ◆ May decrease by 10 to 30 beats/min after 6 months of moderate training at any given rate of work, with the decrease being greater at higher rates of work

## Maximal

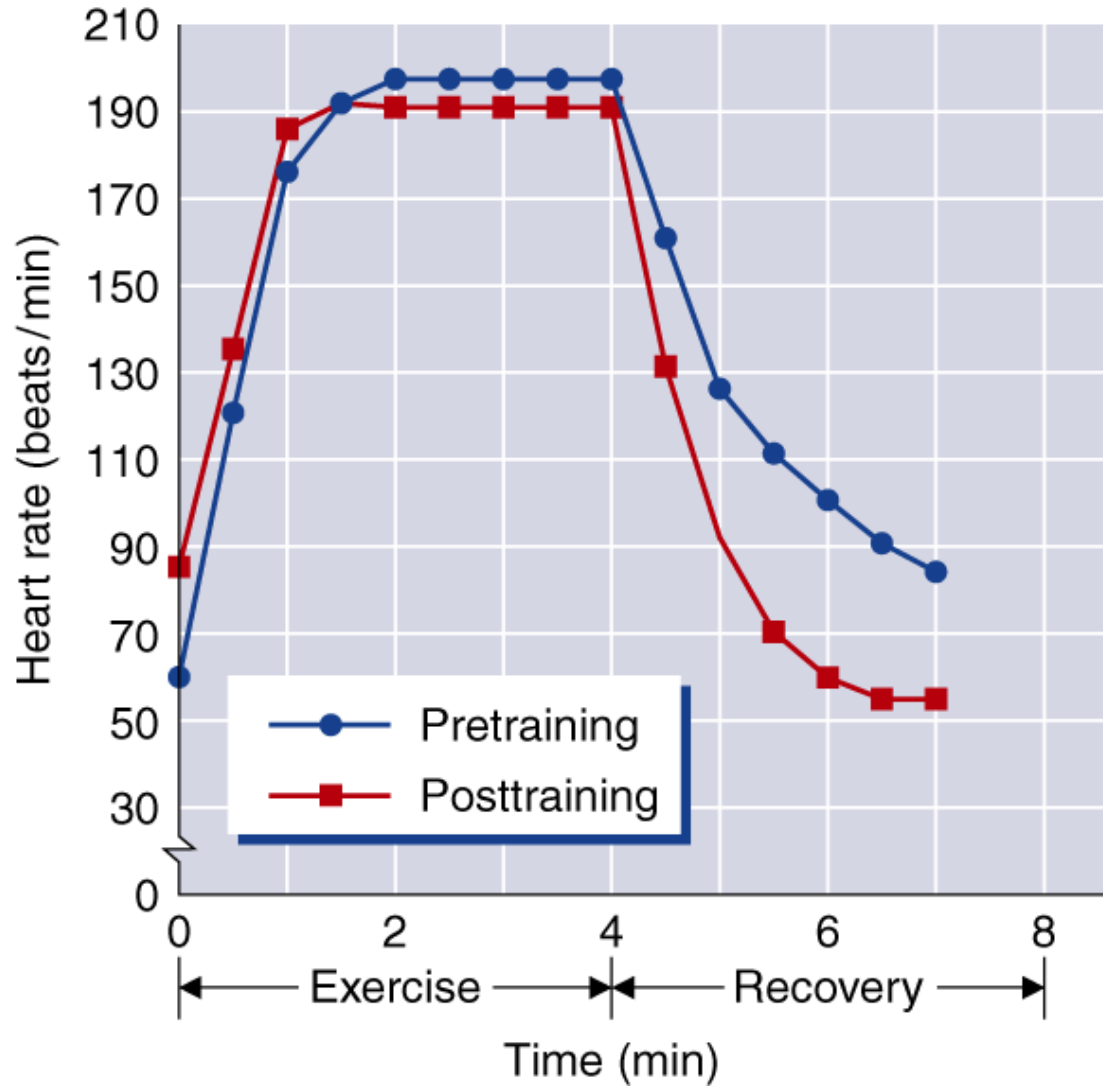
- ◆ Remains unchanged or decreases slightly
- ◆ A decrease might allow for optimal stroke volume to maximize cardiac output

# Heart Rate Recovery Period

- ◆ The time after exercise that it takes your heart to return to its resting rate
- ◆ With training, heart rate returns to resting level more quickly after exercise
- ◆ Has been used as an index of cardiorespiratory fitness
- ◆ Conditions such as altitude or heat can affect it
- ◆ Should not be used to compare individuals to one another



# HEART RATE RECOVERY AND TRAINING

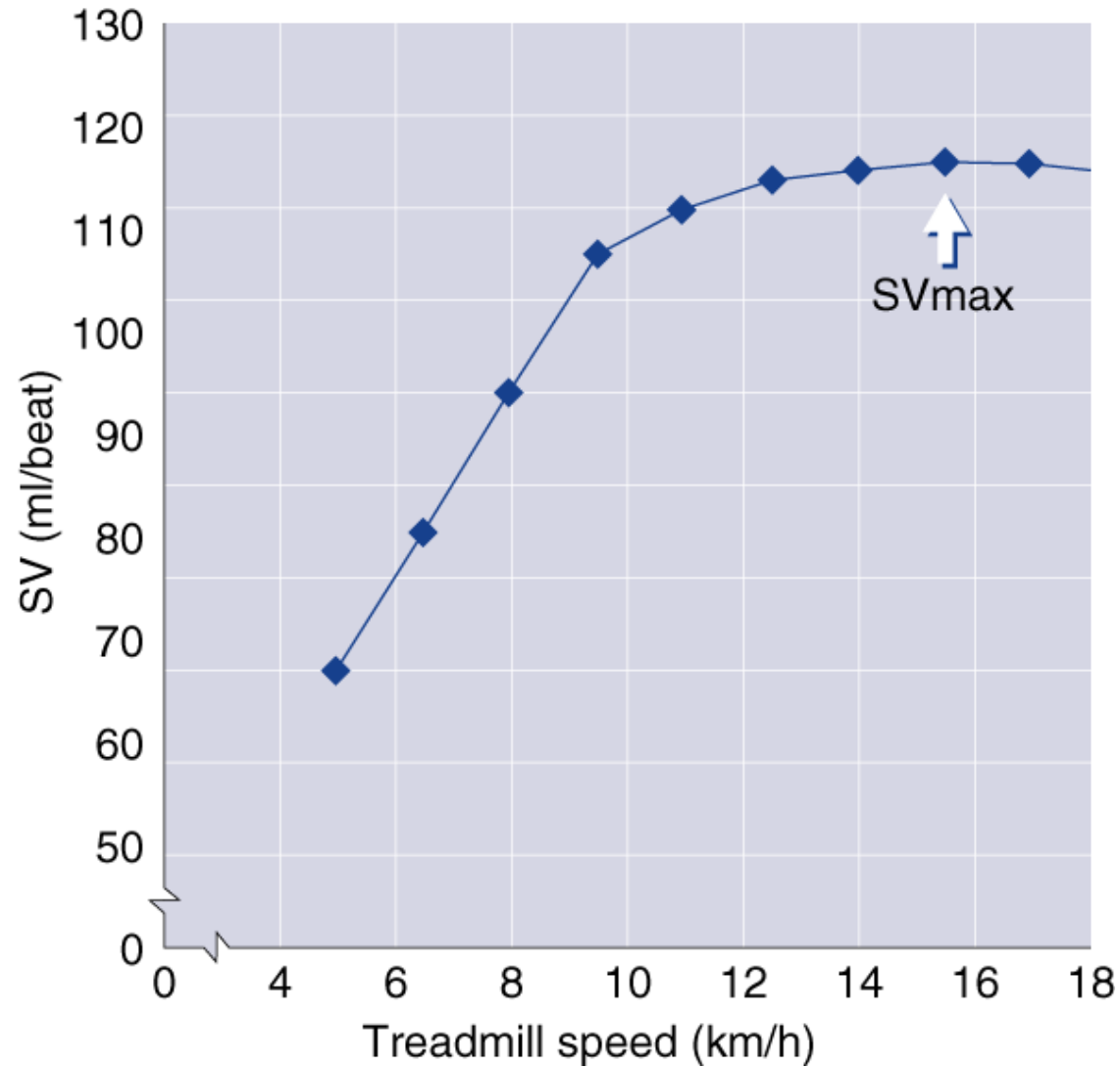


# Stroke Volume

- ◆ Determinant of cardiorespiratory endurance capacity at maximal rates of work
- ◆ Increases with increasing rates of work up to intensities of 40% to 60% of max or higher
- ◆ May continue to increase up through maximal exercise intensity, generally in highly trained athletes
- ◆ Magnitude of changes in SV depends on position of body during exercise

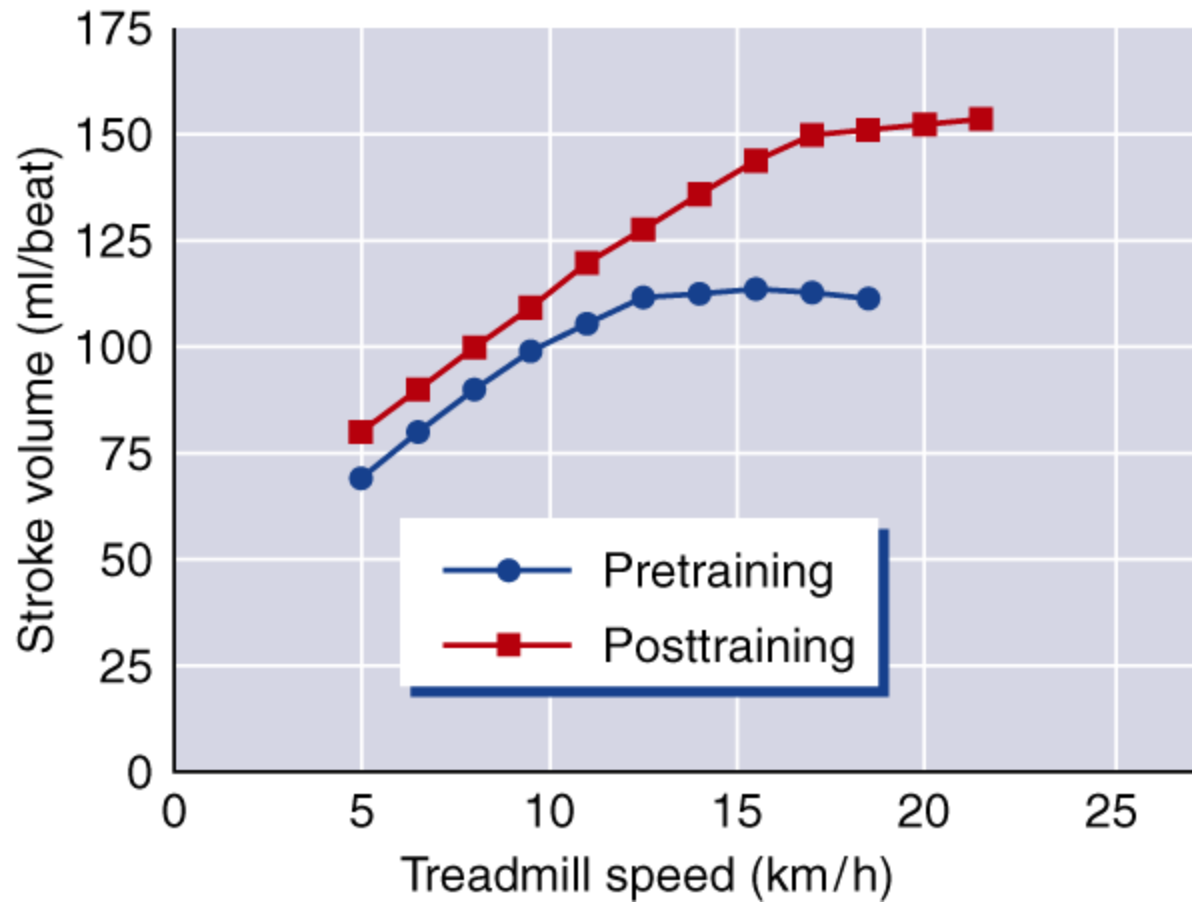


# STROKE VOLUME AND INTENSITY





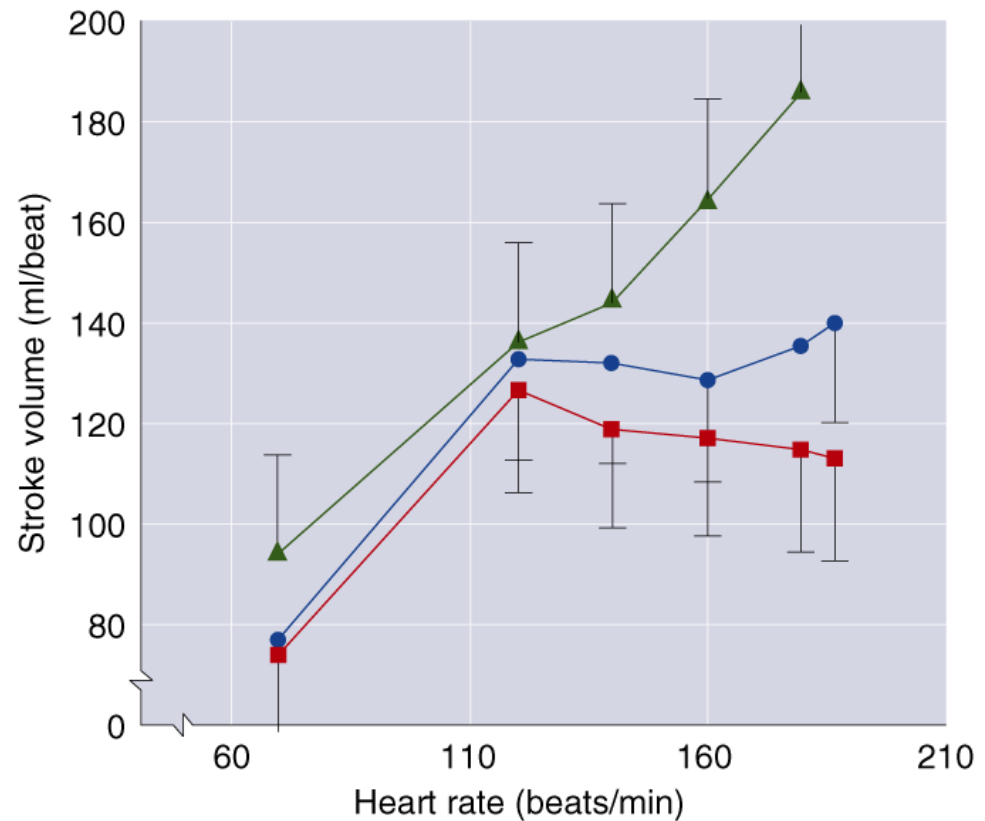
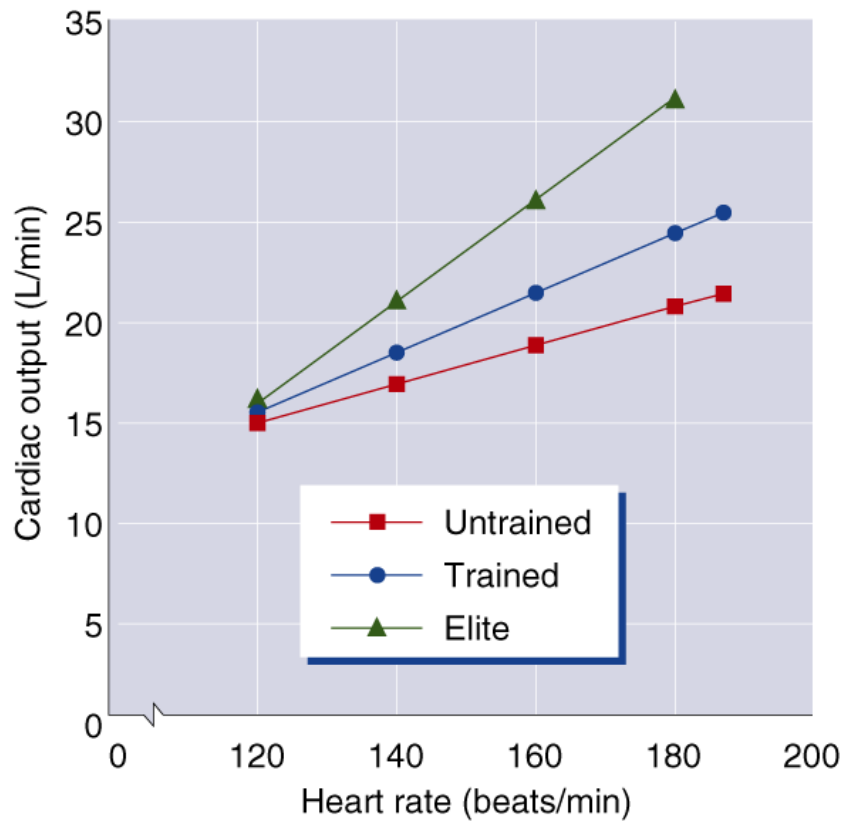
# STROKE VOLUME AND TRAINING



## Stroke Volumes (SV) for Different States of Training

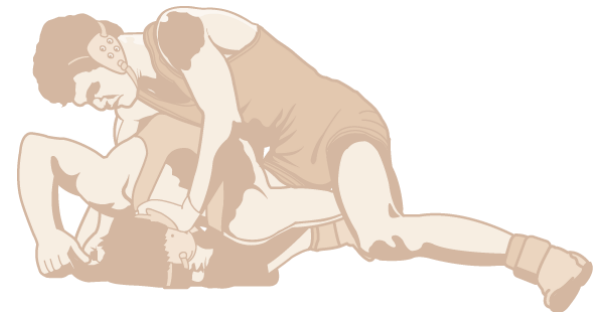
<b>Subjects</b>	<b>SVrest (ml)</b>	<b>SVmax (ml)</b>
Untrained	50-70	80-110
Trained	70-90	110-150
Highly trained	90-110	150-220

# CHANGES IN $\dot{Q}$ AND SV WITH INCREASING RATES OF WORK

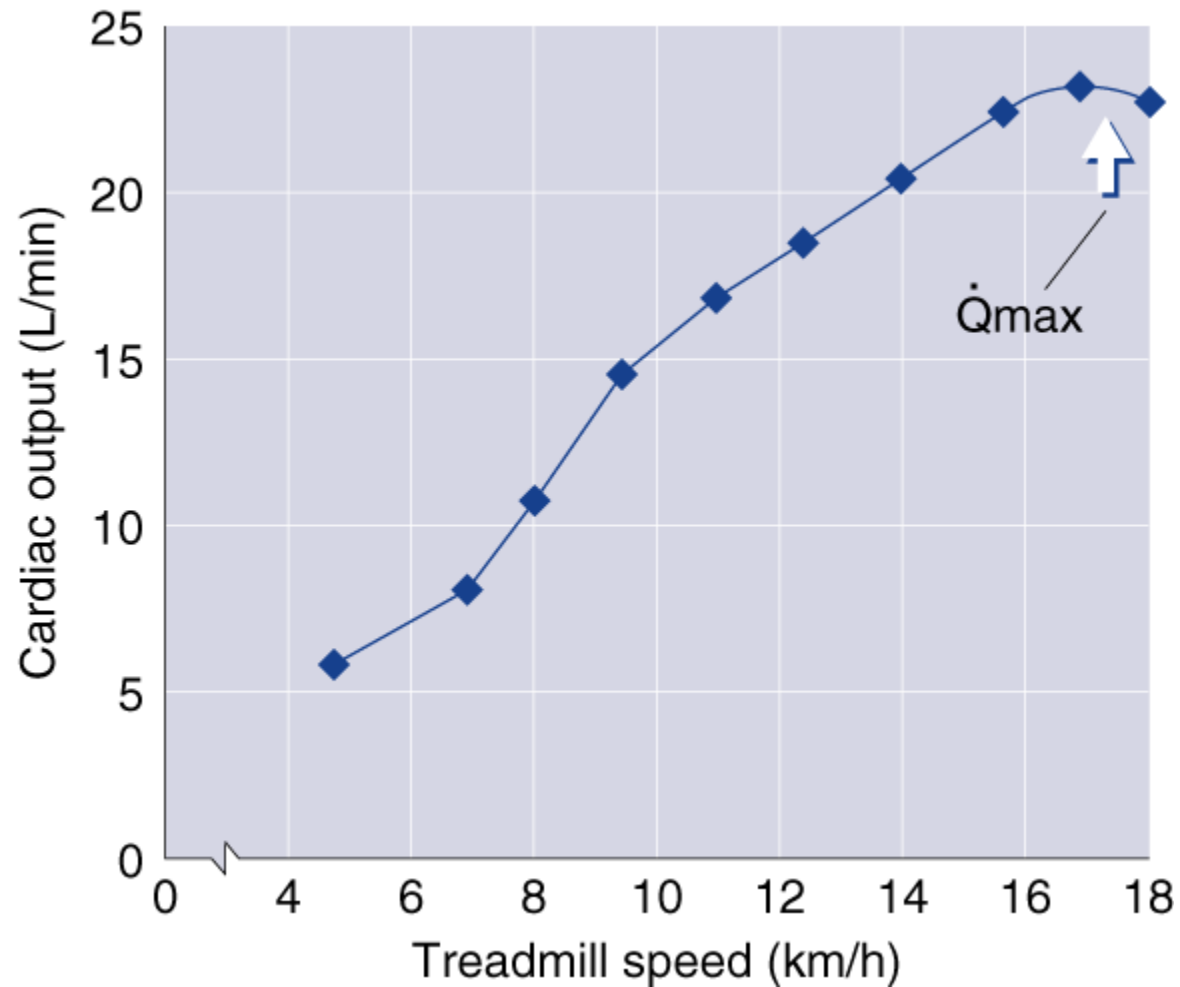


# Cardiac Output

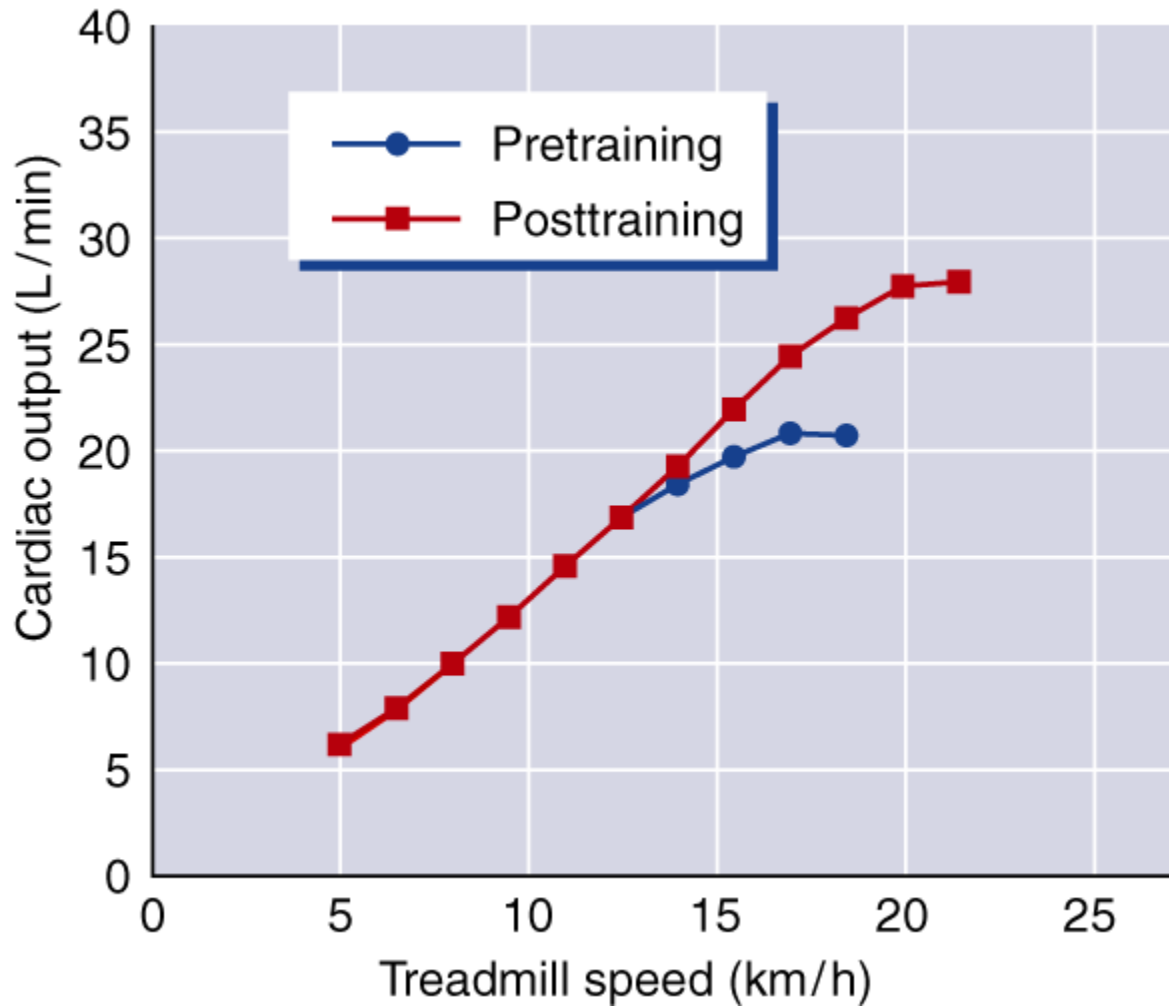
- ◆ Resting value is approximately 5.0 L/min.
- ◆ Increases directly with increasing exercise intensity to maximal values of between 20 to 40 L/min.
- ◆ The magnitude of increase varies with body size and endurance conditioning.
- ◆ When exercise intensity exceeds 40% to 60%, further increases in  $\dot{Q}$  are more a result of increases in HR than SV since SV tends to plateau at higher work rates.



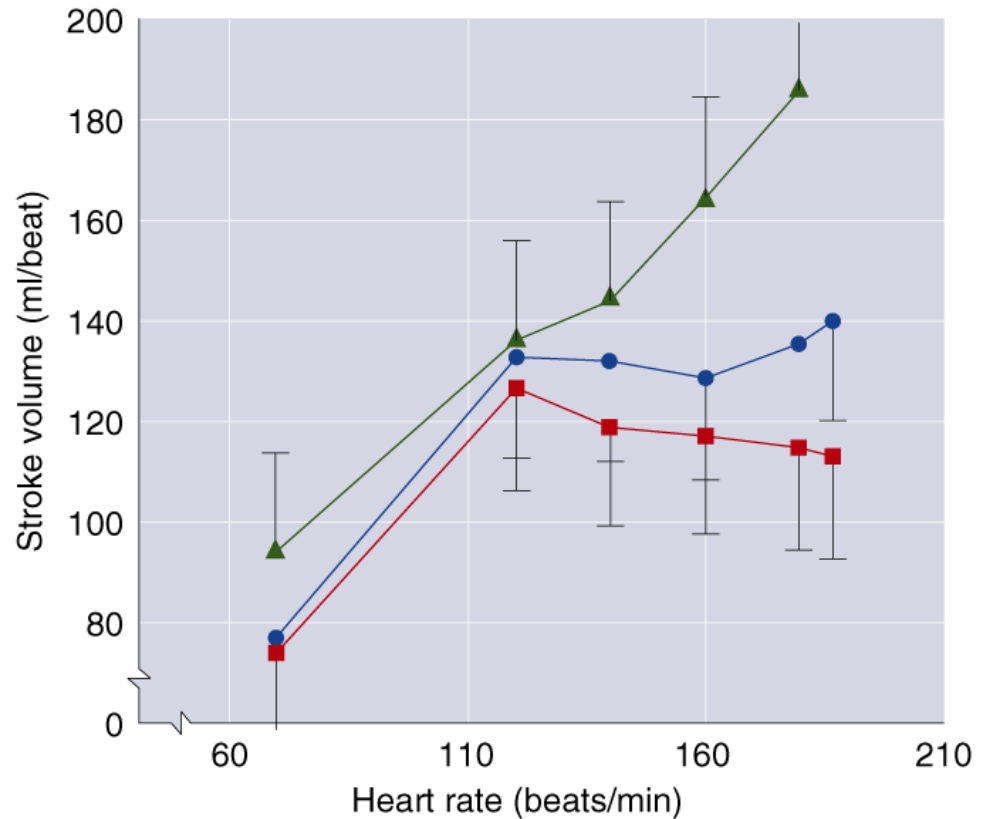
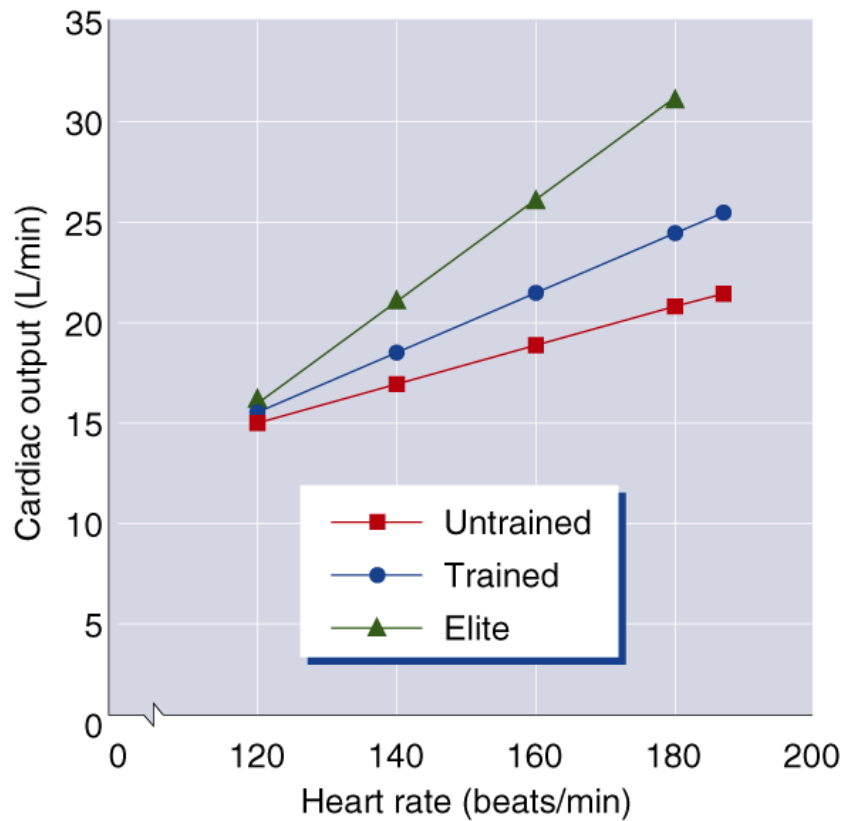
# CARDIAC OUTPUT AND INTENSITY



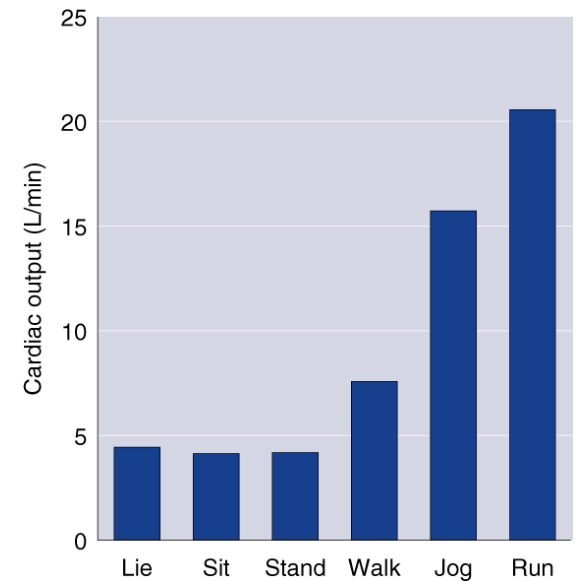
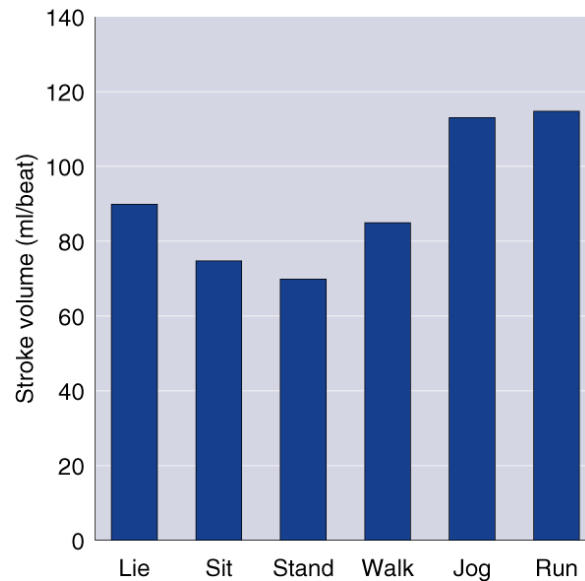
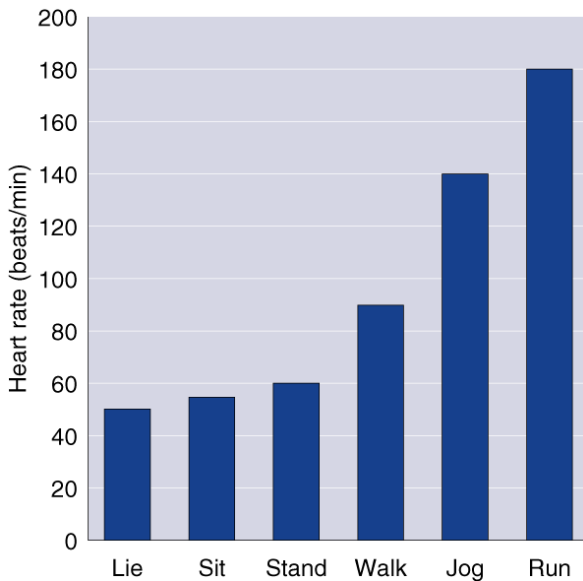
# CARDIAC OUTPUT AND TRAINING



# CHANGES IN $\dot{Q}$ AND SV WITH INCREASING RATES OF WORK



# CHANGES IN HR, SV, AND Q WITH CHANGES IN POSITION AND EXERCISE INTENSITY





# Blood Pressure

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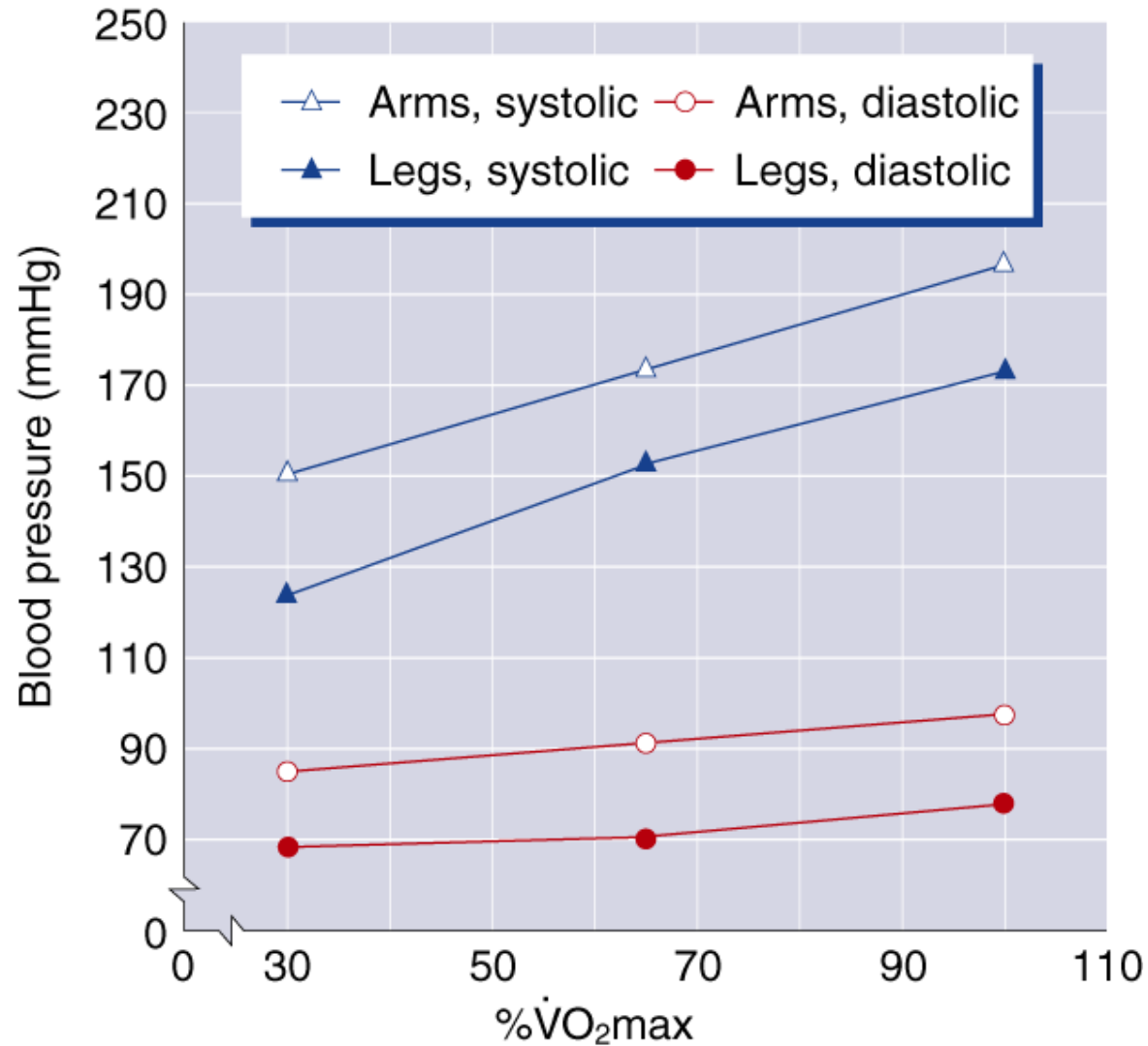
## Cardiovascular Endurance Exercise

- ◆ Systolic BP increases in direct proportion to increased exercise intensity
- ◆ Diastolic BP changes little if any during endurance exercise, regardless of intensity

## Resistance Exercise

- ◆ Exaggerates BP responses to as high as 480/350 mmHg

# BLOOD PRESSURE RESPONSES



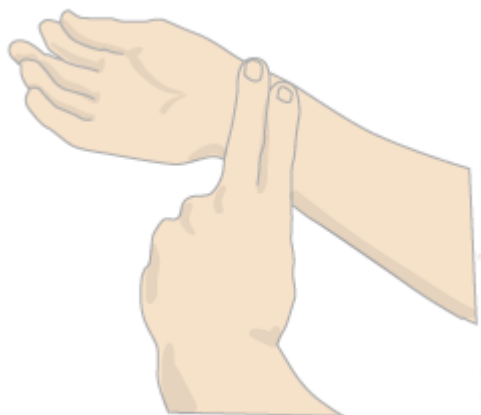
# Cardiovascular Adaptations to Training

- ◆ 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

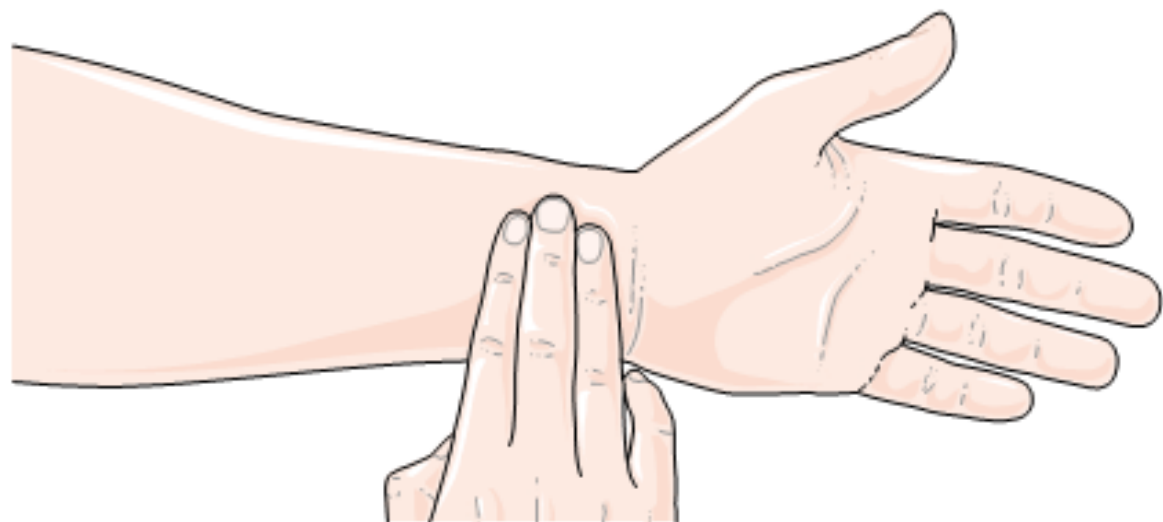




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# Sphygmomanometer

