

Cardiac Output Control

This answer is oriented to dentistry students.

Cardiac Output

is the amount of blood pumped by the heart per unit of time and it depends on

1. Stroke volume (SV) = the amount of blood ejected per beat of the heart (Normally, 70 ml/beat)
2. Heart rate (HR) = heart beats per minute (normally, 70 beats/min)

Heart Rate

- Varies between about 60 to 180 (200) beats/minute
- Marked increases in Heart Rate cause a proportional decrease in diastolic filling time which could result in lower volume of blood ejected (unless venous return is increased)
- Elevated Heart Rate can increase contractility, independent of sympathetic effect
- Trained individuals can maintain the same cardiac output during rest and exercise with lower Heart Rate (bradycardia)
- Sympathetic stimulation causes increase of Heart Rate
- Parasympathetic stimulation causes decrease of Heart Rate
- In experiments, an increase in pressure in the atria (particularly in LA) produces tachycardia (Bainbridge reflex) which is a 100% Vagal (Parasympathetic) reflex

Stroke Volume

- Stroke volume of the left and right chamber over any significant period of time are the same
- In the Right Ventricle (*consider it a segment of a sphere thus $V = \frac{4}{3}\pi R^3$*) relatively large volumes of blood are ejected as a result of small changes in fiber length. At the same time, the pressure is low.
- The Left Ventricle is thick-walled (*consider it a cylinder thus $V = \pi R^2 h$*), so greater fiber shortening must occur to eject the same volume of blood, but the pressure reached is higher
- **Exercise induced hypertrophy**
 - causes an increase of the heart's capacity to generate a large stroke volume

Frank-Starling Mechanism of the heart

- **The length of cardiac fibers at the end of the diastole determines the stroke volume independently of neural regulation**
- When the muscle length is stretched prior to contraction (the end diastolic volume is larger), the heart contracts more forcibly (thus increasing stroke volume)
 - Neural (sympathetic & parasympathetic) and humoral (epinephrine) factors can substantially influence this parameter of the heart activity
- When the muscle length is stretched beyond at critical point, the developed force is decreased
- The end diastolic volume is determined by
 - Central Venous Pressure (CVP)
 - Compliance of the ventricles
 - Filling time
- Ejection of Blood is determined by
 - Arterial Pressure
 - Contractility of myocardium

Efficiency of the Heart

- The external work done by the heart is much less than the energy equivalent of the oxygen consumed by the myocardium
- The greater part of the energy is used on internal work that is dissipated in heat
- The ratio of useful work performed to energy requirement is referred to as the **efficiency** which is about 10-20%
- Decreased when heart when there is increased resistance
- Increased when stroke volume increases

Mechanism of the increase in the arterial pressure during exercise

- Due to exercise, the metabolism in the active skeletal muscles causes the local muscle arterioles to relax allowing an influx of nutrients and oxygen for the tissue
- This greatly decreases the total peripheral resistance, which should decrease the arterial pressure too. This does not happen since the nervous system instantly compensates.

- The brain activity that send the signals to the skeletal muscles simultaneously activates the autonomic nervous system centers of the brain to stimulate the circulatory system, initiating
 - Increased heart rate
 - Large vein constriction
 - Increased contractility of the heart
- These actions cause an increase in the arterial pressure above normal, which causes increased blood flow through the active muscles

References

Prof. Jaroslav Pokorný Lecture & Notes