Cardiovascular Response to Exercise

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Exercise physiology is the study of the effect of exercise on body systems. Exercise is beneficial for health. However, as a result, oxygen and nutrient demand increases several folds, a lot of energy is required, which comes from the stored energy resources of the body. In order to provide sufficient oxygen for respiration to occur, the workload on the lungs and heart increases several folds. The blood supply to other organs is also compromised; for example, during exercise, the blood flow to the digestive tract is reduced. This is to allow sufficient blood flow to the skeletal muscles.

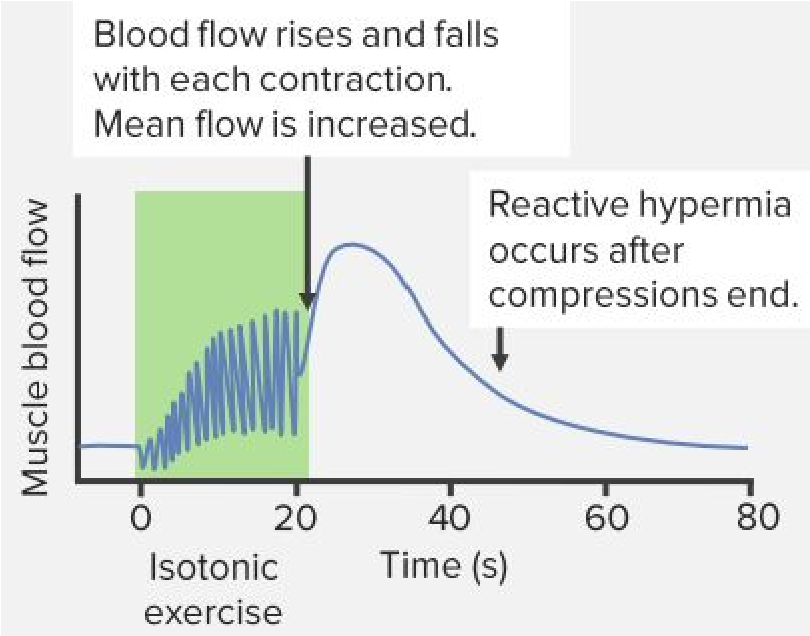
The cardiovascular system responds to exercise in different ways depending on the type of exercise.

Isotonic and Isometric Resistance Exercise

Isotonic resistance exercises involve the shortening and lengthening of the muscle. Isotonic resistance exercise, also known as **dynamic constant external resistance (DCER)** builds both muscle strength as well as endurance. Examples include any exercise that involves lifting and lowering weights, lunges, or opening and closing joints, such as pressing and curls or squatting, which are considered isotonic.

Similar changes in HR, SVR, and muscle blood flow is seen in isometric exercise, except:

- Blood flow rises after each contraction
- Results in an active hyperemia blood flow pattern



"Isotonic Resistance Exercise" Image created by Lecturio

Isometric exercises, on the other hand, challenge your muscles without any joint movement and the length of the muscle remains consistent. The resistance is due to the force of **gravity**. It is often referred to as '**static strength training**' as the person only holds a certain position rather than moving.

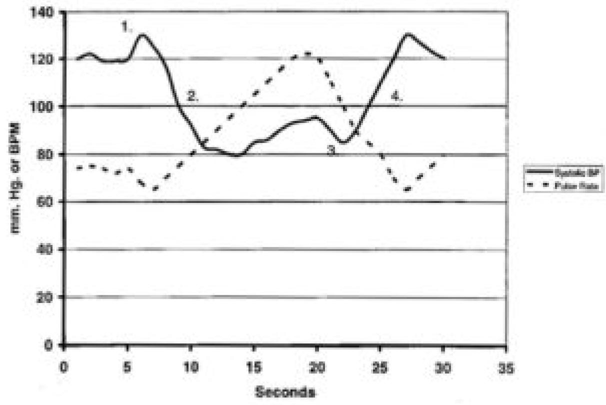
An example would be performing a plank, where your core muscles are strengthened while at a fixed length or carrying heavy weights such as shopping bags where your arm muscles are contracted although they are not necessarily moving.

Blood Pressure Effects of the Valsalva Maneuver

The Valsalva maneuver describes a **forceful exhalation against a closed epiglottis**, which happens whenever you strain to lift something heavy and especially in **isometric exercise**.

The Valsalva maneuver increases intra-abdominal pressure, which is necessary to stabilize your spine from within but also causes a dramatic rise in blood pressure. The Valsalva maneuver can cause blood pressure to rise from a normal resting level of 120 mmHg to over 300.

The blood pressure changes occurring as a result of this maneuver are:



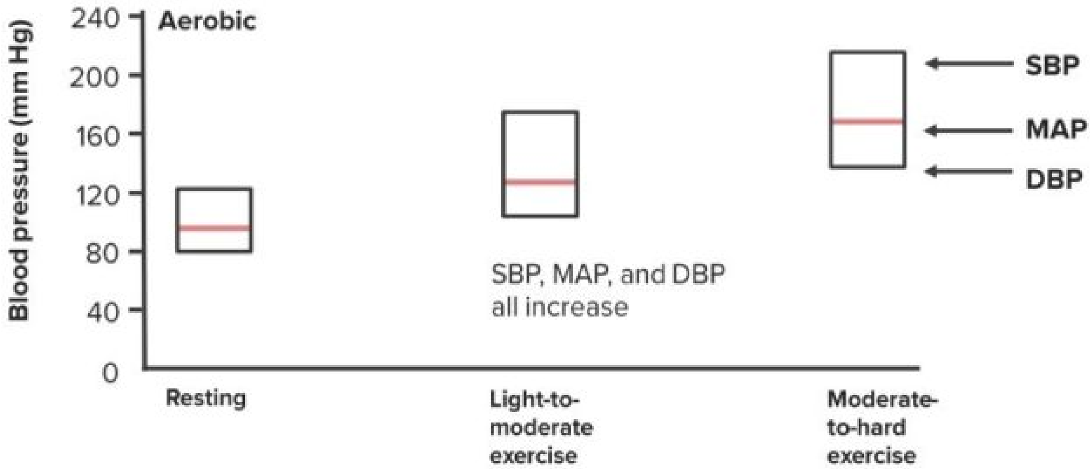
[Image](#): "Systolic blood pressure and pulse rate changes during Valsalva maneuver." by T.torda at English Wikipedia – Own work. License: [Public Domain](#)

On the application of full expiratory force, the blood from the **pulmonary circulation** shifts into the **left atrium**. This increases the stroke volume and an initial rise in **systolic blood pressure**, at 5 seconds, labeled as 1 in the graph.

Due to increased **intrathoracic pressure**, the **venous return** decreases. This results in a decrease in the stroke volume. The blood pressure initially drops to 5—15 seconds (labeled as 2) but soon **vasoconstriction** occurs, which causes a slight rise in the blood pressure. The decrease in the stroke volume causes **reflex tachycardia** shown in the graph.

As the pressure of the chest cavity decreases after exhalation, the **pulmonary vessels** fill with blood again. This causes decreased return of blood to the **left atrium** causing a decrease in blood pressure at 20—23 seconds (labeled as 3). The decrease in the stroke volume is soon compensated by an increase in the venous return. The blood pressure begins to rise again from 23—27 seconds.

The stroke volume initially rises above normal (labeled 4) due to a rush of blood into the **ventricle** and returns to the normal value at 30 seconds. The **pulse rate**, which was increased due to decreased **cardiac output** also returns to the normal value.

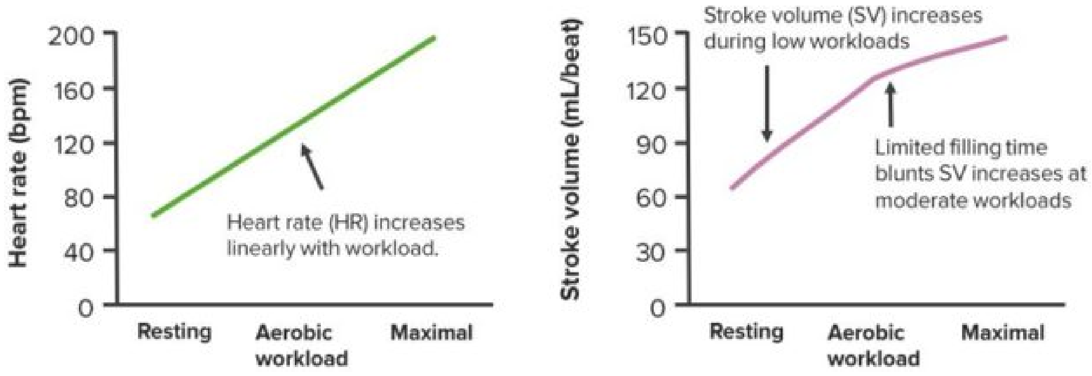


"ABP Response to Resistance Exercise" Image created by Lecturio

Endurance Training

When a person engages in daily or regular exercise, certain responses are produced in their body to increase its efficiency and capacity.

The **cardiac output** increases as the rate of oxygen demand increases. However, this linear relationship has a certain limit after which the cardiac output stays constant. The **heart rate** increases as the oxygen demand increases in order to maintain a constant cardiac output.



“CO Changes in Endurance Exercise” Image created by Lecturio

When a person is at rest, only 20 % of the cardiac output goes to the skin and the skeletal muscles. However, when they are exercising, more blood needs to flow toward the highly metabolic skeletal muscles. This is to allow the provision of more oxygen and removal of waste products such as carbon dioxide. It is estimated that up to 80 % of the cardiac output is supplied to the skeletal muscles and the skin in exercise.

If the **external temperature** is higher, then more blood flows to the skin in order to keep the internal body temperature constant.

The **long-term cardiovascular changes** occurring as a result of endurance training include little change in the cardiac output at rest and sub-maximal exercises.

However, at the maximal level of exercise, the cardiac output increases by up to 30 %. After training, stroke volume is increased at rest, during sub-maximal and at maximal training. The **heart rate**, on the other hand, is decreased at rest and sub-maximal training. It may remain unchanged during maximal training.

The increase in stroke volume in endurance training is due to an **increase in the blood volume**. This is due to **increases in the venous return, thus to an increase in end-diastolic volume.** In addition, **hypertrophy** of the cardiac muscles also occurs, which increases the overall force of contraction.

Endurance training also **increases the number of capillaries in the skeletal muscles**. Therefore, more blood can flow. **As the capacitance of the blood increases because of new capillaries formed, the total peripheral resistance decreases.** As a result, plasma volume increases within two to three weeks of endurance training and more blood reaches the right atrium. The left ventricle then can pump more blood into the aorta.

Blood Pressure Response to Endurance Training

Because of the formation of new capillaries, the **arterial blood pressure** decreases as a result of endurance training in **normotensive persons**. After training, the blood pressure at rest, during sub-maximal exercise and maximal exercise is lower than before. This decrease is **greater in hypertensive patients**. For instance, if the decrease in normotensive person is 3 mmHg, the decrease in hypertensive patients is 10 mmHg.

Skeletal Muscle Effects of Chronic Endurance Training

Long-term exercise results in **hypertrophy** of a specific group of muscles. Sometimes, for counterbalance, the opposite group of muscles also undergoes an increase in muscle mass, a phenomenon known as **cross-education**.

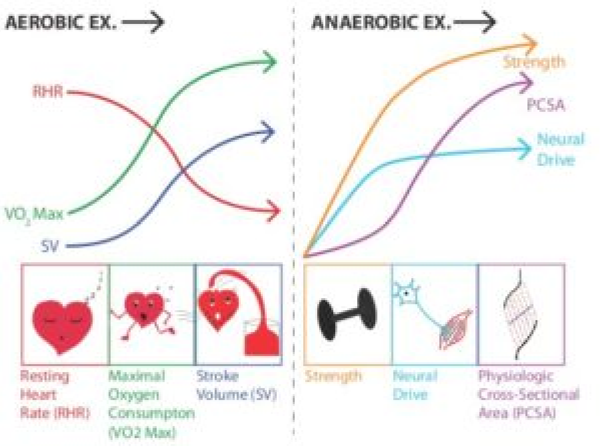


Image: "Summary of adaptations to long-term aerobic and anaerobic exercise." by Plin7 at English Wikipedia. License: CC BY-SA 3.0

The **metabolic capacity** of the muscles also changes with endurance exercise. Muscles performing the anaerobic exercise (white fibers) will start producing more **glycolytic enzymes**. Similarly, muscles performing an aerobic exercise (red fibers) will develop more blood capillaries and **mitochondria**.

Additionally, oxygen extraction from the blood increases, resulting in the prompt supply of energy.

The type of muscle fibers remains unchanged and the presence of a certain type of muscle fibers in certain athletes is genetic.

Aerobic exercise training results in an increase in oxygen consumption and stroke volume while the resting heart rate decreases. Similarly, the **anaerobic exercise training** results in an increase in muscle strength, neural drive, and physiologic cross-sectional area. After anaerobic training such as sprinting and weightlifting, the heart rate stays elevated for several hours.

References

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Notes