Blood Pressure & Effects of Exercise  
Laboratory #3

Assigned reading

Widmaier, et al. *Vander’s Human Physiology*  
Ch. 12

**OBJECTIVES**

1) Learn to measure your blood pressure using a sphygomomanometer.  
2) Test the effect of exercise and body position on cardiac parameters including systolic and diastolic pressures, pulse pressure, mean arterial pressure, and heart rate.

*Please bring a calculator to this lab. Wear closed-toe shoes and glasses instead of contacts.*

**Heart Function**

During this lab you will listen to heart sounds and correlate those sounds with the mechanics of heart function. You will also record blood pressure and heart rate and test the effect of exercise on the timing of various parameters of the blood pressure.

**A. Heart Sounds**  
No doubt you have watched many times as a doctor listened to your heart. Most heart sounds are low frequency (<100Hz) and are thus hard to hear with the equipment we are using in lab today. There are, however, sounds associated with the opening and closing of valves and the turbulent flow of blood that are relatively easy to hear, which you will be able to listen to today.

It is traditional to mention four distinct sounds during the cardiac cycle, but without sufficient training, one usually hears only the two major sounds:
1. “Lub”, the first in a series and the loudest sound, is caused by the closure of the AV valves as ventricular pressure rises above atrial pressure.

2. “Dub”, the second in a series and less audible than the lub, is caused by the closure of the aortic and pulmonary semilunar valves as ventricular pressure falls below atrial pressure.

Use your stethoscope to listen to your heart or your lab partner’s heart sounds. If you don’t hear anything, check that the toggle on the end of the stethoscope is flipped up (towards you) and that you are using the flat round part of the device. If the lab is noisy, do this in the hall.

B. Blood and Pulse Pressure

The rhythmic expulsion of blood from the left ventricle into the arterial system produces a blood pressure in the aorta and large arteries. Blood pressure rises to a maximum (systolic pressure) during the contraction of the left ventricle and then falls to a minimum (diastolic pressure) when the left ventricle relaxes to fill for the next contraction. The difference between systolic and diastolic pressures is called the pulse pressure. Blood pressures are recorded as systolic/diastolic pressure (e.g., 120 mmHg / 70 mmHg). Note that the terms systole/systolic and diastole/diastolic are generally used to refer to ventricular state or pressure, although one can also refer to atrial systole/diastole.

Stephen Hales was the first (in 1731) to measure blood pressure. He inserted a hollow tube (cannula) into a large artery of a horse and measured the height to which the arterial blood ascended. We use a less drastic method: balancing the unknown blood pressure against a second, known pressure. The sphygmomanometer (a mouthful – so the term ‘blood pressure cuff’ is most often used) consists of a rubber bag surrounded by a stiff cloth cuff that can be inflated and deflated to specific, measured pressures. Pressure in the bag is measured by a manometer (pressure measuring device). When the bag and cuff are placed around the arm and deflated, the pressure of gas within the bag is transmitted to the arm tissues (including blood vessels). The cuff is inflated until its pressure cuts off flow through the brachial artery. Then the cuff is slowly deflated while you use the stethoscope to listen for turbulent blood flow through the artery, which makes the sounds you hear.

To measure blood pressure:

1. Empty the cuff of all air and wrap it around the upper arm (just above the elbow) of a seated subject.
2. Apply the stethoscope just below the cuff and a little above the crease of the elbow.
3. Pump up the cuff to a pressure of 180 mmHg and then gradually release the pressure, while listening for blood flow with the stethoscope. (If you are using the automated pump, then just press the start button while listening with the stethoscope).
4. Listen for two events:
a. When the maximum blood pressure during systole is equal to cuff pressure, a little blood will be pushed through the artery and you will hear that blood flow as a “blrrp” or a “tap”. Note the blood pressure when you first hear the sound – this is the systolic pressure. The sound will become louder as cuff pressure continues to decrease (and blood flow increases).

b. Cuff pressure will continue to decrease. Continue listening – at some point the sound will abruptly cease. Record that pressure; this is the diastolic pressure.

Note: Do not leave the cuff pumped up for more than two or three minutes, since the arm will become engorged or ischemic and all subsequent measurements will be inaccurate. If you have trouble hearing, do this in the hall.

Remember that the ear-holes of the stethoscope go forward, toward your eyes. If you put them in backwards you won’t be able to hear the heart sounds.

Also remember that your brachial artery is located lateral to the vein where blood is commonly taken for blood donations or hematology samples. You should be able to feel a pulse before you put the cuff on.

C. Cardiac Function During Exercise:

In this lab we will measure blood pressure and heart rate when the body is in different positions, directly after exercise and at two-minute intervals following exercise.

The amount of blood leaving the heart per minute is known as cardiac output (CO) because it’s a volume per time which is equal to the product of stroke volume (the volume ejected by the heart per beat) and heart rate.

\[
\text{Cardiac Output (L/min)} = \text{Stroke Volume (L/beat)} \times \text{Heart Rate (beats/min)}.
\]

At rest CO is usually about 5-6 L/min, but changes during exercise. For an individual, CO correlates linearly with their \( \dot{V}_{O_2} \) over the scope of aerobic behavior. At the onset of exercise, CO changes because of increases in both HR and SV. SV increases are mediated by the “Frank-Starling law of the heart”, which ensures that “what comes in
must go out”, or more technically that the heart increases its contractile strength with increasing volume so that the end-diastolic volume of the heart determines SV. End-diastolic volume can be increased by increasing the pressure in the venous system. Venous pressure is usually relatively low (~5 mmHg), but can increase through several factors, some of which are increased during exercise. Because the heart is only so big, increases in CO during more demanding levels of exercise are mediated almost exclusively through increases in HR (Figure 4). These increases in HR are caused initially by decreases in parasympathetic stimulation and later by increases in sympathetic stimulation of the SA node of the heart.

In addition to measuring heart rate we will measure systolic and diastolic blood pressure while the body is in different positions, directly after exercise and at five two-minute intervals following exercise. Systolic pressure is the pressure generated by the heart during contraction, while diastolic is the residual blood pressure during relaxation. We’ll examine how these values, and the difference between them (Pulse Pressure), change during exercise.

Mean arterial pressure (MAP) is the average pressure in the cardiovascular system. We will calculate mean arterial pressure in this lab by calculating a weighted average using the following formula:

\[
MAP = P_D + \frac{1}{3}P_P
\]

Where \(P_D\) is the diastolic pressure and \(P_P\) is the pulse pressure (systolic pressure – diastolic pressure). The pressure driving blood through capillaries acts like any fluid...
moving through limited space. This pressure (MAP) depends on the resistance to fluid movement (known as total peripheral resistance or TPR) through the circulatory system and the amount of fluid attempting to pass through that resistive space (CO).

\[ \text{MAP} = \text{CO} \times \text{TPR} \]

We know that CO increases during exercise, but we also want to know what happens to TPR. As muscles are used, they increase their perfusion by opening arterioles. This vasodilation is due to both hormonal effects (such as circulating epinephrine) and local responses to hypoxia (such as the release of nitric oxide). The amount of blood going into exercising muscle can increase by as much as 20 times! As muscle arterioles open, TPR is reduced, offsetting the effects of increased CO on MAP. In this lab we will measure MAP and estimate CO, so that we can assess how exercise affects TPR.

Experimental set up

You should spend some time working with your partner and get familiar taking his or her blood pressure. Once you are capable of relying taking blood pressure measurements on the first try you should measure your partners blood pressure and heart rate under the following conditions after laying down for two minutes, after sitting for two minutes, after standing for two minutes, directly post-exercise (exercise should last for at least 10 minutes) and five measurements taken at two-minute intervals following exercise.

You’ll need the following data for analysis:

- Heart Rate (beats/min) (HR)
- Systolic Blood Pressure
- Diastolic Blood Pressure
## Data Collection Tables:

<table>
<thead>
<tr>
<th>Trial</th>
<th>Heart Rate (b/min)</th>
<th>Systolic BP (mmHg) ($P_s$)</th>
<th>Diastolic BP (mmHg) ($P_d$)</th>
<th>Mean Arterial Pressure</th>
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<tbody>
<tr>
<td>Rest – Lying Down</td>
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<td>Rest - Sitting</td>
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<td>Rest - Standing</td>
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<td>Immediately Post-Exercise</td>
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<td>Two Minutes Post-Exercise</td>
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<td>Ten Minutes Post-Exercise</td>
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Laboratory Report

Due to your TF (by email) at the beginning of the next lecture period (20pts):

1) Using Excel or another graphing program plot HR, MAP, and Systolic, Diastolic and Pulse Pressures against measured time after exercise. Do not use the same set of axes for two different variables. (5 points)

2) How are the cardiac responses that you observed mediated in response to exercise? Discuss in terms of (1) local responses (responses at the level of tissue O\textsubscript{2} demand) and (2) autonomic nervous system control of the cardiovascular system, and (3) baroreceptor mediated control of blood pressure. This is a chance for you to practice explaining physiological processes, be economical but comprehensive. (6 points)

4) Why do people who are in shape tend to have lower resting heart rates than those who aren’t in shape? (3 points)

5) Describe three aspects of your cardiovascular system that might increase in the long term (due to genetic inheritance - i.e. breeding, or training) and would result in an increase your capacity for oxidative exercise? (6 points)