PHY100's Lab: The Relationship Between Liquid Pressure and Depth as it applies to Blood Pressure

Name:_______________________________________ Course & Sec:_______

Lab Partner:_____________________________________ Date:___________

Disclaimer: The procedures in this lab are not according to proper clinical protocols. This lab is not intended to teach how to take vital signs or instruct on emergency procedures.

Materials: Wrist Blood Pressure Monitor, 2 meter sticks, lab jack, barometer

Background:
Blood pressure is the force exerted by the blood on the walls of the arteries. A blood pressure measurement of the brachial artery is usually expressed as a fraction. The units of the fraction are millimeters (mm) of mercury (Hg), because traditionally, the device used to measure blood pressure (a sphygmomanometer) uses mercury in its gauge. The numerator in this fraction refers to the systolic pressure, which is the peak pressure created when the left ventricle of the heart contracts and forces blood into the aorta. The denominator of the fraction refers to the diastolic pressure, which is the reduced pressure of the blood as it continues to move forward between the contractions of the ventricles. The blood pressure of someone with a systolic pressure of 120 and a diastolic pressure of 80 would be expressed as 120 / 80 mm Hg (16 kPa / 10.5 kPa).

The automatic instrument used in this lab to measure blood pressure employs the oscillometric method. The cuff is inflated rapidly so that the artery of the arm is compressed and the passage of the blood is stopped. Then, the cuff is gradually deflated until minute pulsations are perceived by the sensor in the device as the blood starts pumping through the artery. The measurement is the maximum or systolic pressure.

A blood pressure measurement of a vessel is affected by several factors, one of the most important of which is the diameter of the blood vessel. Other factors include the elasticity of the vessel, the viscosity of the blood, and the distance between the heart and the place where the blood pressure is measured. We will explore the last of these factors through this lab as we measure blood pressure at the wrist. For a given person, the distance between the wrist and the heart is fixed with regard to the length of that circulation path. However, a change in the orientation of that path will result in a change in the blood pressure measurement as the wrist is held at various heights. Think of a blood vessel as a long fluid filled tube and consider any point on the inner wall of this tube. The pressure (force/area) exerted by the fluid on this point will depend on the magnitude of the pumping force (as provided by the heart muscle), the speed of the fluid at this point, and the weight of the fluid above this point.

The pressure exerted by a liquid at any point in the liquid, due to the weight of the liquid above, follows the relationship: Liquid pressure = weight density of the liquid x depth within the liquid $P = \rho \times g \times h$ in units of N/m^2 or Pascals ($1\ N/m^2 = 1$ Pascal).

If the tube's orientation is altered, by being flipped vertically or horizontally, then a given point in the tube may experience a change in pressure since the depth in the liquid at that point may have changed. This difference in pressure will depend on the changed depth within the liquid as:
$\Delta P = \rho \times g \times \Delta h$, where Δh is the change in depth, and assume weight density remains constant.

Experiment:
The objective is to quantify the effect by which liquid pressure varies with depth as it relates to blood pressure measurements taken at the wrist height relative to the heart. A total of 3 blood pressure readings will be taken on 2 individuals in your group. For the 1st individual, measurements will be taken while the person is seated. For the 2nd individual, measurements will be taken while the person is standing. The height of the wrist wearing the cuff will be varied in each of the three readings for each person.

Use of Wrist Blood Pressure monitor:
1. A measurement taken within 30 minutes of eating, smoking, or exercising will not be your "true" blood pressure.
2. With the palm of your left hand up, put the cuff on your wrist so that the main body is on the same side as your palm.
3. Adjust the cuff, with your palm up, until its edge is positioned ¼ to ½ inches (5 to 10 mm) from the lowest part of your palm.
4. Fasten the cuff around your wrist so that there is no space between the cuff and your wrist. The cuff should fit snugly. Press the surface of the cuff to make sure that it is attached securely.
5. Attach the cuff next to your skin only. Take care that your clothes are not caught by the cuff. Do not push the POWER button before the cuff is completely wound.
6. Do not support your own arm. Support should be provided by a table or another person holding it. If the patient holds his own arm the readings will be higher due to isometric activity. Lightly open your hand.
7. Do not move, chat or strain your arm or hand during the measurement. Do not cross your legs.
8. Breathe deeply 5 or 6 times to relax before the measurement.
9. Press the POWER button. If you hold the button down too long (more than 2 seconds) the power will be turned off.
10. The apparatus automatically starts inflation. Record the reading when the measurement is finished.
11. To stop the measurement for any reason, press the POWER button and the apparatus will stop inflation, discharge air rapidly, and then turn off.
12. Wait at least 5 minutes between measurements. Use the same wrist for repeated measurements.

Initial Calculations:
1. The column of mercury fluid in a barometer will reach a vertical height of 0.7600m (760.0mm) at Standard Atmospheric pressure (measured at sea-level at 0ºC). Use the formula for Liquid Pressure on page 1 to calculate the atmospheric pressure supporting that column of mercury in N/m^2. This unit is also called Pascals (Pa). Use: density ρ of mercury at 0ºC ~ 13595 kg/m^3, g = 9.803 m/s^2.

Std. Atm. Pressure:____________________ N/m^2 or Pa Today's Pressure:____________________

2. Calculate the conversion factor you will need to use throughout this lab to convert from Pascals to mm Hg. To do this, specify how many Pa equal one mm Hg:

$$\frac{\text{Std. Atm Pressure}}{\text{Std. Height of Hg}} = \frac{\_\_\_\_\_\_\_\_\_\_}{760.0 \text{ mm Hg}} = \qquad\qquad \text{Pa/mm Hg}$$

Data Set 1: **All three measurements taken on Person 1 while seated**

**Measure to the same black dot on the cuff for every wrist height measurement.

A. Seated, wrist resting on lap:
Height of wrist above the floor: ______________ cm ____________ m

Systolic Diastolic

___________ mm Hg ______________ mm Hg

B. Seated, wrist at heart level:
Height of wrist above the floor: ______________ cm ____________ m

Systolic Diastolic

___________ mm Hg ______________ mm Hg

C. Seated, elbow raised to shoulder height, wrist elevated to head height:
Height of wrist above the floor: ______________ cm ____________ m

Systolic Diastolic

___________ mm Hg ______________ mm Hg

Analysis:
1.) Measured change in systolic pressure between positions A and B, ΔP in mm Hg:

Change in height, Δh between positions A and B:

Prediction of change in systolic pressure between A and B, ΔP in Pascals, by calculation:
$\Delta P = \rho \times g \times \Delta h$ Use ρ of blood ~ 1,040 kg/m^3

Convert this ΔP prediction to mm Hg using the conversion factor:

Find % difference between measured and predicted ΔP. If result is less than 60%, finish all data collection before troubleshooting. If none of your % differences are less than 20% or any one is greater than 60%, look for errors. Consult instructor as necessary:

2.) Measured change in systolic pressure between positions A and C, ΔP in mm Hg:

Change in height, Δh between positions A and C:

Prediction of change in systolic pressure between A and C, ΔP in Pascals, by calculation:
$\Delta P = \rho \text{ x } g \text{ x } \Delta h$ Use ρ of blood ~ 1,040 kg/m^3

Convert this ΔP prediction to mm Hg using the conversion factor:

Find % difference between measured and predicted ΔP:

<u>Conclusions:</u>
In which position was the measured systolic blood pressure the highest and the lowest?

For a seated person under normal conditions, is the blood pressure higher in the head or in the feet? Support your answer by relating liquid pressure with depth in the liquid.

<u>Data Set 2:</u> All three measurements taken on Person 2 while standing
Again, refer to <u>Use of Wrist Blood Pressure monitor:</u> on page 2, particularly #6 and #12.

D. Standing, wrist down:
Height of wrist above the floor: ______________ cm ____________ m

<u>Systolic</u> <u>Diastolic</u>

___________ mm Hg ______________ mm Hg

E. Standing, wrist at heart level:
Height of wrist above the floor: ______________ cm ____________ m

<u>Systolic</u> <u>Diastolic</u>

___________ mm Hg ______________ mm Hg

F. Standing, elbow raised to shoulder height, wrist elevated to head height:
Height of wrist above the floor: ______________ cm ____________ m

<u>Systolic</u> <u>Diastolic</u>

___________ mm Hg ______________ mm Hg

<u>Analysis:</u>
1.) Measured change in systolic pressure between positions D and E, ΔP in mm Hg:

Change in height, Δh between positions D and E:

Prediction of change in systolic pressure between D and E, ΔP in Pascals, by calculation:
$\Delta P = \rho \times g \times \Delta h$ Use ρ of blood ~ 1,040 kg/m^3

Convert this ΔP prediction to mm Hg using the conversion factor:

Find % difference between measured and predicted ΔP:

2.) Measured change in systolic pressure between positions D and F, ΔP in mm Hg:

Change in height, Δh between positions D and F:

Prediction of change in systolic pressure between D and F, ΔP in Pascals, by calculation:
$\Delta P = \rho \times g \times \Delta h$ Use ρ of blood ~ 1,040 kg/m^3

Convert this ΔP prediction to mm Hg using the conversion factor:

Find % difference between measured and predicted ΔP:

Conclusions:

For Data set 2, in which position was the measured systolic blood pressure the highest and the lowest?

If blood pressure is monitored around the ankle of a seated person, how would the measurement compare with one taken at the wrist at heart level?

If blood pressure is monitored simultaneously at the wrist and also at the ankle of the same person lying down flat on their back, how would these two measurements compare ?