

### Blood pressure. Arterial and venous circulation

#### Introduction

Hales first measured blood pressure in 1733 by inserting tubes directly into the arteries of animals. Non-invasive techniques for the measurement of blood pressure have been in existence since the early 1800s, although Scipione Riva-Rocci, an Italian physician, is credited with developing the first conventional sphygmomanometer in 1896. In 1905, Nicolai Korotkoff described various sounds while auscultating over the brachial artery during deflation of a Riva-Rocci cuff.[1]

Although the System International d’unités (SI) unit of pressure is the Pascal [equivalent to 1 Newton per square meter (N/m²)], by convention, blood pressure is measured in millimeters of mercury (mm Hg).

Blood pressure (BP) is the force exerted by circulating blood on the walls of blood vessels, and constitutes one of the principal vital signs. The pressure of the circulating blood decreases as blood moves through arteries, arterioles, capillaries, and veins; the term blood pressure generally refers to arterial pressure, i.e., the pressure in the larger arteries, the blood vessels that take blood away from the heart.

![Blood pressure graph](image)

Fig. 1 - As blood travels through the arterial system, resistance from the walls of the blood vessels reduces the pressure and velocity of the blood.

#### Systolic and Diastolic Blood Pressure

For each heartbeat, blood pressure varies between systolic and diastolic pressures. Systolic pressure (SBP) is peak pressure in the arteries, which occurs near the beginning of the cardiac cycle when the ventricles are contracting. Diastolic pressure (DBP) is minimum pressure in the arteries, which occurs near the end of the cardiac cycle when the ventricles are filled with blood. An example of normal measured values for a resting, healthy adult human is 115 mmHg systolic and 75 mmHg diastolic (written as 115/75 mmHg). Pulse pressure is the difference between systolic and diastolic pressures.

Systolic and diastolic arterial blood pressures are not static but undergo natural variations from one heartbeat to another and throughout the day (in a circadian rhythm). They also change in response to stress, nutritional factors, drugs, disease, exercise, and momentarily from standing up. Sometimes the variations are large. Hypertension refers to arterial pressure being abnormally high, as opposed to hypotension, when it is abnormally low.

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'Normal' blood pressure varies with age, state of health and clinical situation. At birth, a typical blood pressure is 80/50 mmHg. It rises steadily throughout childhood, so that in a young adult it might be 120/80 mmHg. As we get older, blood pressure continues to rise and a rule of thumb is that normal systolic pressure is age in years + 100. Blood pressure is lower in late pregnancy and during sleep.

From this, you can see that a systolic pressure of 160mmHg for an elderly man or 90 mmHg for a pregnant woman may be quite normal. To judge whether any particular reading is too high or too low, we must compare the reading with the 'normal' for that patient.

**Mean Arterial Pressure**

The mean arterial pressure (MAP) is a term used in medicine to describe an average blood pressure in an individual. It is defined as the average arterial pressure during a single cardiac cycle.

The mean arterial pressure (MAP) is determined by the cardiac output (CO), systemic vascular resistance (SVR), and central venous pressure (CVP) according to the following relationship, which is based upon the relationship between flow, pressure and resistance:

\[
MAP = (CO \times SVR) + CVP
\]

Therefore, changes in either CO or SVR will affect MAP. If CO and SVR change reciprocally and proportionately, then MAP will not change. For example, if CO doubles and SVR decreases by one-half, MAP does not change (if CVP = 0).

In practice, MAP is not determined by knowing the CO and SVR, but rather by direct or indirect measurements of arterial pressure. At normal resting heart rates, MAP can be approximated by the following equation:

\[
MAP = DBP + \frac{1}{3}(SBP-DBP)
\]

Likewise to SBP and DBP, MAP varies during lifetime – at birth 70 mmHg, adults 100 mmHg, elder 110 mmHg, and elder with atherosclerosis 140 mmHg.

**Differential Pressure (Pulse Pressure)**

The pulse pressure or differential pressure is the difference between systolic and diastolic blood pressure and represents the force that your heart generates each time it contracts.

\[
\text{Pulse Pressure} = \text{Systolic Pressure} - \text{Diastolic Pressure}
\]

In a person with a systolic blood pressure of 120 mmHg and a diastolic pressure of 80 mmHg, the pulse pressure would be 40 mmHg.

The rise in aortic pressure from its diastolic to systolic value is determined by the compliance of the aorta as well as the ventricular stroke volume. In the arterial system, the aorta has the highest compliance, due in part to a relatively greater proportion of elastin fibers versus smooth muscle and collagen. This serves the important function of dampening the pulsatile output of the left ventricle, thereby reducing the pulse pressure (systolic minus diastolic arterial pressure). If the aorta were a rigid tube, the pulse pressure would be very high. Because the aorta is compliant, as blood is ejected into the aorta, the walls of the aorta expand to accommodate the increase in blood volume. As the aorta expands, the increase in pressure is determined by the compliance of the aorta at that particular range of volumes. The more compliant the aorta, the
smaller the pressure change during ventricular ejection (i.e., smaller pulse pressure). Therefore, aortic compliance is a major determinant, along with stroke volume, of the pulse pressure.

**Arterial pulse. Sphygmogram.**

The ejection of blood in the aorta by the left ventricle systole generates two different processes. The first process consists in the propulsion of the blood volume along the arteries at a velocity of 0.2-0.6 m/s. The other process occurs in the walls of the arteries, as a wave initiated at the root of the aorta that travels distally and propagates through the arterial wall of all arteries. This wave is called the “arterial pulse” or “pressure of pulse” (not to be mistaken for pulse pressure) and can be perceived as a pulsatile wave when taking the pulse. This wave travels 15 times faster than blood at a velocity of 3-5 m/s in the aorta, 7-10 m/s in large arteries and 15-35 m/s in small arteries. The velocity can change with age due to arteriosclerosis.

The pulse can also be recorded as an expansion of the arterial wall or as a wave of pressure. The *sphygmogram* represents the recording of the pulsatile wave at the level of large arteries. Recorded simultaneously with ECG and phonocardiogram, the sphygmogram can offer information on the cardiac output and the duration of heart systole phases.

The sphygmogram can be recorded:
- Invasively through the catheterization of a large artery
- Non-invasively using a pressure transducer, a piezoelectric sensor (arteriopiezogram) or a photoelectric (infrared) transducer

The sphygmogram has the following components:
- Systolic ascending slope or anacrotic slope rises at 75° – 80° to the horizontal plane. Gives rise to the Percussion wave (P wave). The height of P wave and the fast ejection time (which lasts for 0.08 – 0.10s) of the left ventricle is related to the ejection ability of heart and the compliance index of aorta. A larger slope indicates a better performance of the heart ejection function and aorta compliance. Thus it is used as a quantitative feature to evaluate the cardiovascular system.
- The second peak, called the Tidal wave (T wave), appears when blood hits the artery wall and rebounds. As a result, T wave manifest if the artery possesses excellent elasticity that reflects low peripheral resistance of the circulatory system. On the other hand, an artery with a stiff wall makes the T wave propagate fast. Accordingly, the T wave will merge with the P wave, which results in a wider P wave. The time between the peaks of the P and T wave is also known as the systolic plateau, lasting 0.14s.
- Finally, when the aortic valve is closed, the Dicrotic wave (D wave) is generated. The height of the D wave will decrease due to a stiff aorta or aortic regurgitation. The descending slope of the sphygmogram is also called catacrotic slope.

The sphygmogram can change in pathological conditions (some examples are given below):

<table>
<thead>
<tr>
<th>pulsus tardus et parvus</th>
</tr>
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<tbody>
<tr>
<td>It is seen in aortic valve stenosis. With respect to aortic stenosis, “typical findings include a narrow pulse pressure.</td>
</tr>
</tbody>
</table>
pulsus bisferiens
Bisferious means striking twice. Classically, it is detected when aortic insufficiency exists in association with aortic stenosis, or in severe Ao. insufficiency

pulsus alternans
is a physical finding with arterial pulse waveform showing alternating strong and weak beats. It is almost always indicative of left ventricular systolic impairment, and carries a poor prognosis.

pulsus paradoxus (Kussmaul sign)
is an exaggeration of the normal variation in the pulse during the inspiratory phase of respiration, in which the pulse becomes weaker as one inhales and stronger (>10mmHg) as one exhales. It is a sign that is indicative of several conditions including cardiac tamponade, pericarditis, chronic sleep apnea, croup, and obstructive lung disease

Blood Pressure Measurement Methods
Arterial pressures are usually measured non-invasively (indirectly), without penetrating skin or artery. Measuring pressure invasively (directly), by penetrating the arterial wall to take the measurement, is much less common, and usually restricted to a hospital setting.

Non-Invasive Blood Pressure Measurement
A. Auscultatory method
The auscultatory method was described for the first time by Nikolai Korotkoff in 1905 being currently the most widely used method for BP measurement. It uses a stethoscope and a sphygmomanometer. This comprises an inflatable (Riva-Rocci) cuff placed around the upper arm at roughly the same vertical height as the heart, attached to a mercury or aneroid manometer. The mercury manometer measures the height of a column of mercury, giving an absolute result without need for calibration, and consequently not subject to the errors and drift of calibration which affect other methods. The use of mercury manometers is often required in clinical trials and for the clinical measurement of hypertension in high risk patients, such as pregnant women.

Fig. 2 – Types of sphygmomanometers. Left: mercury sphygmomanometer; Right – aneroid sphygmomanometer.

The principle on which the auscultatory method relies is the inflation of the cuff compressing the brachial artery hence causing the artery to collapse once the systolic pressure (the maximum pressure exerted by the blood against the wall of the brachial artery when the heart beats) has been exceeded.

The valve on the pump is loosened slowly to allow the pressure of the sphygmomanometer cuff to decrease. Once the systolic pressure is reached the brachial artery opens causing volatile
blood flow, which causes vibrations against the artery walls. These noises are called Korotkoff sounds (named after their discoverer) and can be heard through a stethoscope as the pressure exerted onto the brachial artery falls. The blood flow through the brachial artery increases steadily, until the pressure of the sphygmomanometer cuff falls below the diastolic pressure. This is the point where the blood flow through the artery is laminar. The Korotkoff sounds are first heard when the cuff pressure equals the systolic pressure, and cease to be heard once the cuff has deflated past the diastolic pressure.

It is generally accepted that there are five phases of Korotkoff sounds. Each phase is characterized by the volume and quality of sound heard.

**Phase 1.** With the pressure cuff inflated to beyond the systolic pressure, the artery is completely occluded and no blood can flow through it. Consequently, no sounds are heard above the systolic pressure. At the point where cuff pressure equals the systolic pressure, a sharp tapping sound is heard. We recall that the blood pressure oscillates between systolic and diastolic pressure. At systolic, the pressure is great enough to force the artery walls open and for blood to spurt through. As the pressure dips to diastolic, however, the artery walls bang shut again. It is the closing shut of the artery walls that results in the tapping sound.

**Phase 2.** This phase is characterized by a swishing sound, caused by the swirling currents in the blood as the flow through the artery increases. Sometimes, if the cuff is deflated too slowly, the sounds vanish temporarily. This happens when the blood vessels beneath the cuff become congested, and is often a sign of hypertension. The congestion eventually clears, and sounds resume. The intervening period is called the auscultatory gap.

**Phase 3.** In this phase, there is a resumption of crisp tapping sounds, similar to those heard in phase 1. At this stage, the increased flow of blood is pounding against the artery walls.

**Phase 4.** At this point, there is an abrupt muffling of sound. The blood flow is becoming less turbulent. Some medical practitioners choose to record this point as the diastolic pressure.

**Phase 5.** This is the point at which sounds cease to be heard all together. The blood flow has returned to normal and is now laminar. The pressure cuff is deflated entirely and removed.

Fig. 3 – A. Cuff inflated above the systolic blood pressure (SBP), no flow occurs distally to the cuff; B. Once the pressure in the cuff descends below the SBP, soft-intermittent tapping sounds are being heard; C. The pressure in the cuff approaches the diastolic blood pressure (DBP) value, muffled sound are being heard; D. The cuff is deflated below DBP – no sounds are heard.

**Preparation for measurement**

Before the blood pressure measurement begins the following conditions should be met:

1. Subjects should abstain from eating, drinking (anything else than water), smoking and taking drugs that affect the blood pressure one hour before measurement.
2. Because a full bladder affects the blood pressure it should have been emptied.
3. Painful procedures and exercise should not have occurred within one hour.
4. Subject should have been sitting quietly for about 5 minutes.
5. Subject should have removed outer garments and all other tight clothes. The sleeve of shirts, blouses, etc. should have been rolled up so that the upper right arm is bare. The remaining garments should not be constrictive and the blood pressure cuff should not be placed over the garment.
6. Blood pressure should be measured in a quiet room with comfortable temperature. The room temperature should have been recorded.
7. The time of day should have been recorded.

Position of the subject
Measurements should be taken in sitting position so that the arm and back are supported. Subject’s feet should be resting firmly on the floor, not dangling. If the subject’s feet do not reach the floor, a platform should be used to support them.

Position of the arm
The subject’s arm should be resting on the desk so that the antecubital fossa (a triangular cavity of the elbow joint that contains a tendon of the biceps, the median nerve, and the brachial artery) is at the level of the heart and palm is facing up. To achieve this position, either the chair should be adjusted or the arm on the desk should be raised, e.g. by using a pillow. The subject must always feel comfortable. The measurements should be made on the right arm whenever possible. However, Measure BP in both arms at first consult of a subject/patient to detect possible differences due to peripheral vascular disease. In this instance, take the higher value as the reference one.

Selection of the cuff
The greatest circumference of the upper arm is measured, with the arm relaxed and in the normal blood pressure measurement position (antecubital fossa at the level of the heart), using a non-elastic tape. The measurement should be read to the nearest centimeter. Select the correct cuff for the arm circumference:

<table>
<thead>
<tr>
<th>Cuff width</th>
<th>8 cm</th>
<th>12 cm</th>
<th>16 cm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arm circumference</td>
<td>less than 25 cm</td>
<td>25 cm - 35 cm</td>
<td>over 35 cm</td>
</tr>
</tbody>
</table>

The cuff should be placed on the right arm so that its bottom edge is 2-3 cm above the antecubital fossa, allowing sufficient room for the bell of the stethoscope. The top edge of the cuff should not be restricted by clothing.

Number of measurements
Three measurements should be taken one minute apart. If three measurements are not feasible, two will suffice with a certain loss in data stability.

Procedure of the pulse rate and blood pressure measurement
1. The radial pulse is palpated and the pulse rate is counted for 30 seconds, measured by a digital wrist watch or one with second hand. Record 30-second pulse count and whether pulse was regular.
2. The manometer should be placed so that the scale is at eye level and the column perfectly vertical. The subject should not be able to see the column of the manometer.
3. Determining the peak inflation level:
   a. The mercury column has to be at 0 level.
   b. The subject’s radial pulse is again palpated.
   c. The cuff is inflated and the level of the top of the meniscus of the mercury column is noted at the point when the radial pulse disappears. The cuff is immediately deflated by completely opening the valve.
   d. The peak inflation level is determined by adding 30 mm to the pressure where the radial pulse disappeared.
4. Venous blood pool in the forearm is normalized by waiting at least 30 seconds or by raising the arm for 5-6 seconds.

5. The brachial pulse is located and the bell of the stethoscope is placed immediately below the cuff at the point of maximal pulsation. If it is not possible to feel the brachial pulse, the bell of the stethoscope should be placed over the area of the upper arm immediately inside the biceps muscle tendon. The bell should not touch the cuff, rubber or clothing. The bell of the stethoscope should be used because it gives clearer sounds than the diaphragm.

6. The cuff is rapidly inflated to the peak inflation level and then deflated at a rate of 2 mmHg per second.

7. The pressure should be reduced steadily at this rate until the occurrence of the systolic level at the first appearance of a clear, repetitive tapping sound (Korotkoff Phase 1) and diastolic level at disappearance of repetitive sounds (Phase 5) have been observed. Then the cuff should be rapidly deflated by fully opening the valve of the inflation bulb. Note: There may be a brief period (auscultatory gap) between systolic and diastolic pressure, when no Korotkoff sounds are heard. Therefore, the 2mmHg/second deflation should be continued until the diastolic blood pressure is definitely established. If Korotkoff sounds persist until the cuff is completely deflated, a diastolic blood pressure of 0 should be recorded.

8. The measurements should be recorded to the nearest 2 mmHg. If the top of the meniscus falls half way between two markings, the marking immediately above is chosen. The subject is not told the blood pressure values at this point.

9. After one minute of wait to allow redistribution of blood in the forearm a second measurement is made by repeating steps 6 to 8. The subject should not change position during the wait.

10. After another one minute a third measurement is made by repeating steps 6 to 8.

11. The subject may now be told the measurement values.

B. Doppler ultrasound method
The Doppler method uses a Doppler ultrasound transducer instead of a stethoscope in order to detect flow past the pressurized cuff attached to an aneroid or mercury manometer. The Doppler transducer uses an ultrasound beam to detect blood flow, the signal being displayed on a screen or heard in speakers. This method is useful when the Korotkoff sounds cannot be heard due to very low blood pressures (i.e. hemodynamic shock) or small size arteries (i.e. pediatric patients). Another disadvantage of the method is that diastolic blood pressure cannot be determined. The use of ultrasound gel is essential to allow the passage of ultrasound waves between the transducer and the subcutaneous structures.

C. Photoplethysmography method
This method is also based on the Riva-Rocci principle like the two previously described methods. The device used to detect blood flow distally to the cuff is a pulse plethysmograph sensor. The blood flow signal is usually displayed on a monitor. The method is mainly used in intensive care and research setups.

D. Palpatory method
The palpatory method is another method based on the Riva-Rocci principle. It is mainly used when no devices are available to detect blood flow (i.e. stethoscope, Doppler transducer, etc). Place the cuff of the sphygmomanometer around the arm (as described previously). With one hand, palpate (feel) the radial pulse in the wrist. Slowly inflate the cuff by pumping the bulb with the other hand and note the pressure reading when the radial pulse is first lost. Then increase the pressure to
around 20 mm Hg above this point. Slowly reduce the pressure in the cuff by turning the valve counterclockwise slightly to let air out of the bag. Note the pressure when the radial pulse first reappears. This is systolic blood pressure, the highest pressure in the systemic artery.

The systolic pressure recorded with the palpatory method is usually around 5 mm Hg lower than that obtained using the auscultatory method. A major disadvantage of the palpatory method is that it cannot be used to measure the diastolic pressure.

### E. Ankle brachial pressure index

An ankle brachial pressure index (ABPI) is a simple non-invasive method of identifying arterial insufficiency within a limb. It represents the ratio of the blood pressure in the lower legs to the blood pressure in the arms. Compared to the arm, lower blood pressure in the leg is a symptom of blocked arteries (peripheral vascular disease). The ABPI is calculated by dividing the systolic blood pressure in the arteries at the ankle and foot by the higher of the two systolic blood pressures in the arms.

![ABPI Illustration](image)

The higher of the left and right arm brachial artery pressure is generally used in the assessment. The pressures in each foot's posterior tibial artery and dorsalis pedis artery are measured with the higher of the two values used as the ABPI for that leg.

\[
\text{ABPI} = \frac{\text{SBP Leg}}{\text{SBP Arm}}
\]

The ABPI is a useful tool for the non-invasive assessment of peripheral vascular disease. Studies have shown the sensitivity of ABPI is 90% with a corresponding 98% specificity for detecting hemodynamically significant stenosis >50% in major leg arteries, defined by angiogram.

In a normal subject the pressure at the ankle is slightly higher than at the elbow (there is reflection of the pulse pressure from the vascular bed of the feet, whereas at the elbow the artery continues on some distance to the wrist).

<table>
<thead>
<tr>
<th>ABPI value</th>
<th>Interpretation</th>
</tr>
</thead>
<tbody>
<tr>
<td>above 1.2</td>
<td>Abnormal</td>
</tr>
<tr>
<td></td>
<td>Vessel hardening from peripheral vascular disease</td>
</tr>
<tr>
<td>1.0 - 1.2</td>
<td>Normal range</td>
</tr>
<tr>
<td>0.9 - 1.0</td>
<td>Acceptable</td>
</tr>
<tr>
<td>0.8 - 0.9</td>
<td>Some arterial disease</td>
</tr>
<tr>
<td>0.5 - 0.8</td>
<td>Moderate arterial disease</td>
</tr>
<tr>
<td>under 0.5</td>
<td>Severe arterial disease</td>
</tr>
</tbody>
</table>
F. Oscillation-based methods

Oscillometric method. The method was developed by Victor Pachon, a French physician, in 1909. Pachon’s Oscillometer was a master-piece of creative engineering, which was reputed to be indestructible. The device is difficult to use as the good use of the device is dependant on the user’s ability to recognize and analyze the difference in amplitude between the minima and maxima, which is amplified on the larger of the two displays by a needle linked directly to the pressure in the cuff. The smaller display indicates the constant pressure inside the actual device. To use the device, one has to inflate the cuff to about 200 mmHg (using a little bicycle pump), then slowly let the pressure drop by the using beautifully crafted release valves. As the pressure in the cuff drops, the amplitude of the signal gets greater as more blood flows through the arteries. The point of the device is to judge at what point the amplitude of the signal is greatest. This point is referred to as the Oscillometric Index. In this way, the oscillometer allows the user to estimate the elasticity of the arterial walls and the strength of the pulse wave through the arteries. Pachon’s oscillometer is an improvement over the oscillometer devised by Heinrich von Recklinghausen.

Oscillotonometry. The Von Recklinghausen Oscillotonometer is a device which allows both systolic and diastolic blood pressure to be read without a stethoscope. It consists of two overlapping cuffs (one large, one small) a large dial for reading pressure, a bleed valve and a control lever. The large cuff performs the usual function of the sphygmomanometer cuff. The job of the smaller cuff is basically to amplify the pulsations which occur as the larger cuff is deflated, so that instead of listening for the Korotkoff sounds, they are seen as oscillations of the needle on the pressure gauge. The lever simply switches the dial between the two cuffs.

Wrap the cuff round the arm in the usual way, and inflate it. Adjust the bleed valve so that the pressure falls slowly. Pull the control lever towards you. The needle will jump slightly in time with the pulse. As the cuff pressure approaches systolic, the needle suddenly starts to jump more vigorously. At this point, let go of the lever, and the needle will display systolic pressure. Pull the lever forward again. As the pressure is reduced, the needle jumps more vigorously. If the lever is released at the point of maximum needle oscillations, the dial will read the mean arterial pressure. If it is released at the point when the needle jumps get suddenly smaller, the dial reads diastolic pressure.

Both oscillometric and oscillotonometric methods are nowadays rarely used in their initial form, the principle being applied on automated BP measurement devices.

G. Automatic measurement

Automatic devices which essentially apply the same principle as the oscillotonometer have been produced. They require a supply of electricity. A single cuff is applied to the patients arm, and the machine inflates it to a level assumed to be greater than systolic pressure. The cuff is deflated gradually. A sensor then measures the tiny oscillations in the pressure of the cuff caused by the pulse. Systolic is taken to be when the pulsations start, mean pressure is when they are maximal, and diastolic is when they disappear. They can produce fairly accurate readings and free the hands of the investigator for other tasks. There are important sources of inaccuracy, however. Such devices tend to over-read at low blood pressure, and under-read very high blood pressure. The cuff should be an appropriate size. The patient should be still during measurement. The technique relies heavily on a constant pulse volume, so in a patient with an irregular heart beat (especially atrial fibrillation) readings can be inaccurate. Sometimes an automatic blood pressure measuring device inflates and deflates repeatedly "hunting" without displaying the blood pressure successfully. If the pulse is palpated as the cuff is being inflated and deflated the blood pressure may be estimated by palpation and reading the cuff pressure on the display.

Invasive Blood Pressure Measurement
Direct BP measurement involves placing a needle or catheter into the lumen of an artery. The catheter is then connected via saline-filled tubing to a pressure transducer. The transducer converts the mechanical fluctuations in the fluid into an electrical signal that can be displayed on an oscilloscope or charted on a paper trace. Direct monitoring is considered the “gold standard” of BP measurement. Generally, this method requires sedation or anesthesia for catheter placement. Therefore, although this technique is very useful for intraoperative monitoring, it is less practical for conscious patients. Complications include infection of the catheter, thromboembolism, or serious hemorrhage if the catheter becomes dislodged. Other limiting factors include the technical difficulty of arterial catheterization and the constant attention needed to keep the catheter patent. These complications generally render direct BP measurement unsuitable for routine or outpatient use.

**Physiological Variation of Blood Pressure**

Many physiological conditions can influence the systolic and diastolic blood pressure values. SBP can be increased in emotional states (i.e. anger), cold environment, and physical effort. It can be decreased during sleep, digestion, after physical effort and in professional sportsmen, hot environment, constitutionally. BP can be pathologically increased in situations like hypertension, fever, hyperthyroidism, and decreased in shock, syncope, etc.

**Postural change.** BP changes depending on the posture: lying down (supine/clinostatism), sitting, and standing (orthostatism). The SBP decreases slightly or remain unchanged, meanwhile the DBP increases. Measure your partner's blood pressure while she or he is lying down (supine), sitting, and standing. Record your results on your worksheet and also think about what might cause the changes in pressure that accompany these changes in body position.

**Thermal stress test.** Classically the test is known as the cold pressure test, although hot stimuli produce the same effect. This test is used to demonstrate the effect of a sensory stimulus (cold/hot) on blood pressure. A normal reflex response to such a cold/hot stimulus is an increase in blood pressure (both systolic and diastolic). In a normal individual the systolic pressure will rise no more than 10 mm Hg, but in a hypertensive individual the rise may be 30 to 40 mm Hg. This is why this test is used in some medical systems for hypertension screening purposes.

1. Have the subject sit down comfortably or lie supine in a comfortable environment.
2. Record the systolic and diastolic blood pressure every 5 minutes until a constant level is obtained.
3. Immerse the subject's free hand in ice water (approximately 0-4 °C) to a depth well above the wrist.
4. After a lapse of 10 to 15 seconds, obtain the blood pressure every 20 seconds for 1 or 2 minutes and record. If there is insufficient time to obtain both systolic and diastolic pressure, just measure the systolic value.

Instead of cold water a hot stimulus can be used (40-45°C) like hot water or a Peltier element. Explain the mechanism by which thermal stress influences blood pressure.

**Physical Effort.** This test examines the short-term effects of exercise on blood pressure.

Note – The subject should be in good health, with no known cardiovascular or respiratory problems.

1. Have the subject sit comfortably.
2. Record the systolic and diastolic blood pressure every 5 minutes until a constant level is obtained.
3. Have the subject run up and down several flights of stairs, and then return to the sitting position.
4. Obtain and record the blood pressure immediately, then every minute for 5 minutes. Normally SBP increases instantly with 30-80 mmHg and returns to basal values 2-3 minutes after the effort ceased. DBP remains unchanged or decreases slightly.

**White-coat hypertension.** For some patients, BP measurements taken in a doctor’s office may not correctly characterize their typical BP. In up to 25% of patients, the office measurement is higher than their typical BP. This type of error is called white-coat hypertension (WCH) and can result from
anxiety related to an examination by a health care professional. The misdiagnosis of hypertension for these patients can result in needless and possibly harmful medication. WCH can be reduced (but not eliminated) with automated BP measurements over 15 to 20 minutes in a quiet part of the office or clinic.

References