HEART SOUNDS. PHONOCARDIOGRAM IN BIOPAC SYSTEM

Heart sounds are the noises generated by the beating heart and the resultant flow of blood through it (specifically, the turbulence created when the heart valves snap shut). In cardiac auscultation, an examiner may use a stethoscope to listen, in healthy adults, there are two normal heart sounds often described as a lub and a dub (or dup), that occur in sequence with each heart beat. The “lub” is associated with closure of the atrioventricular (A-V) valves at the beginning of systole, and the “dub” is associated with closure of the semilunar (aortic and pulmonary) valves at the end of systole. The “lub” sound is called the first heart sound, and the “dub” is called the second heart sound, because the normal pumping cycle of the heart is considered to start when the A-V valves close at the onset of ventricular systole. In addition to these normal sounds, a variety of other sounds may be present including heart murmurs, adventitious sounds, and gallop rhythms $S_3$ and $S_4$. Heart murmurs are generated by turbulent flow of blood, which may occur inside or outside the heart. Murmurs may be physiological (benign) or pathological (abnormal). Abnormal murmurs can be caused by stenosis restricting the opening of a heart valve, resulting in turbulence as blood flows through it. Abnormal murmurs may also occur with valvular insufficiency (or regurgitation), which allows backflow of blood when the incompetent valve closes with only partial effectiveness. Different murmurs are audible in different parts of the cardiac cycle, depending on the cause of the murmur.

Causes of the heart sounds.

The general mechanisms that produce sounds: heart valves, chordae tendineae of the myocardium and vessels near the heart.

A. Valve elements: closing valves made against the direction of movement of blood through the heart cavities represent the main source of sounds; opening valves achieved in the direction of blood circulation = DO NOT PRODUCE noisy.

B. Hemodynamic factors: transition of the blood between cordage; collision of two masses of blood with different acceleration creates turbulence; transition of the blood from an area to another with smaller section creates turbulence.

C. Muscle elements: putting the power of ventricular muscle, contraction of ventricular myocardium

D. Vascular elements: distension of the aorta and pulmonary artery during rapid ejection phase; vibration of arterial wall.

The earliest explanation for the cause of the heart sounds was that the “slapping” together of the valve leaflets sets up vibrations. However, this has been shown to cause little, if any, of the sound, because the blood between the leaflets cushions the slapping effect and prevents significant sound. Instead, the cause is vibration of the taut valves immediately after closure, along with vibration of the adjacent walls of the heart and major vessels around the heart. That is, in generating the first heart sound, contraction of the ventricles first causes sudden backflow of blood against the A-V valves (the tricuspid and mitral valves), causing them to close and bulge toward the atria until the chordae tendineae abruptly stop the back bulging. The elastic tautness of the chordae tendineae and of the valves then causes the back surging blood to bounce forward again into each respective ventricle. This causes the blood and the ventricular walls, as well as the taut valves, to vibrate and causes vibrating turbulence in the blood. The vibrations travel through the adjacent tissues to the chest wall, where they can be heard as sound by using the stethoscope.
The second heart sound results from sudden closure of the semilunar valves at the end of systole. When the semilunar valves close, they bulge backward toward the ventricles, and their elastic stretch recoils the blood back into the arteries, which causes a short period of reverberation of blood back and forth between the walls of the arteries and the semilunar valves, as well as between these valves and the ventricular walls. The vibrations occurring in the arterial walls are then transmitted mainly along the arteries. When the vibrations of the vessels or ventricles come into contact with a "sounding board," such as the chest wall, they create sound that can be heard.

Heart sounds are systolic and diastolic.

The first heart tone, or $S_1$, forms the "lub" of "lub-dub". It is caused by the sudden block of reverse blood flow due to closure of the atroventricular valves, i.e. tricuspid and mitral (bicuspid), at the beginning of ventricular contraction, or systole. When the ventricles begin to contract, so do the papillary muscles in each ventricle. The papillary muscles are attached to the tricuspid and mitral valves via chordae tendineae, which bring the cusps or leaflets of the valve closed (chordae tendineae also prevent the valves from blowing into the atria as ventricular pressure rises due to contraction). The closing of the inlet valves prevents regurgitation of blood from the ventricles back into the atria. The $S_1$ sound results from reverberation within the blood associated with the sudden block of flow reversal by the valves. It is a deaf and suppressed sound, grave, with the maximum intensity at the apex. Duration: from 0.08 to 0.12 sec and the tone is low. It occurs after 0.02 to 0.04 the onset of wave Q.

Graphically there are 3 groups of vibration which composed this sound:
- Presegment M1: low-amplitude, low frequency component caused by muscle
- Mainstream T1: generated by closing mitral, tricuspid
- Post segment generated by the aorta and pulmonary artery distension during rapid ejection.

The second heart tone, or $S_2$, forms the "dub" of "lub-dub" and is composed of components $A_2$ and $P_2$. Normally $A_2$ precedes $P_2$ especially during inspiration when a split of $S_2$ can be heard. It is caused by the sudden block of reversing blood flow due to closure of the semilunar valves (the aortic valve and pulmonary valve) at the end of ventricular systole, i.e. beginning of ventricular diastole. As the left ventricle empties, its pressure falls below the pressure in the aorta. Aortic blood flow quickly reverses back toward the left ventricle, catching the pocket-like cusps of the aortic valve, and is stopped by aortic (outlet) valve closure. Similarly, as the pressure in the right ventricle falls below the pressure in the pulmonary artery, the pulmonary (outlet) valve closes. The $S_2$ sound results from reverberation within the blood associated with the sudden block of flow reversal. Splitting of $S_2$, also known as physiological split, normally occurs during inspiration because the decrease in intrathoracic pressure increases the time needed for pulmonary pressure to exceed that of the right ventricular pressure. It is a thud and dry sound with maximum intensity in left space III and II. Duration: 0.04 to 0.06 sec and it occurs after T wave.

Graphically this sound is composed by three groups of vibrations:
- Mainstream has two components caused by the closure of the aorta and pulmonary artery
- Post segment seldom falls, small amplitude, low frequency (produced by the mitral and tricuspid opening).

Rarely, there may be a third heart sound also called a protodiastolic gallop, ventricular gallop. It occurs at the beginning of diastole after $S_2$ and is lower in pitch than $S_1$ or $S_2$ as it is not of valvular origin. The third heart sound is benign in youth, some trained athletes, and sometimes in pregnancy but if it re-emerges later in life it may signal cardiac problems like a failing left ventricle as in dilated congestive heart failure (CHF). $S_3$ is thought to be caused by
the oscillation of blood back and forth between the walls of the ventricles initiated by inrushing blood from the atria. The reason the third heart sound does not occur until the middle third of diastole is probably that during the early part of diastole, the ventricles are not filled sufficiently to create enough tension for reverberation. It may also be a result of tensing of the chordae tendineae during rapid filling and expansion of the ventricle. In other words, an S3 heart sound indicates increased volume of blood within the ventricle. An S3 heart sound is best heard with the bell-side of the stethoscope (used for lower frequency sounds). A left-sided S3 is best heard in the left lateral decubitus position and at the apex of the heart, which is normally located in the 5th left intercostal space at the midclavicular line. A right-sided S3 is best heard at the lower-left sternal border. The way to distinguish between a left and right-sided S3 is to observe whether it increases in intensity with inspiration or expiration. A right-sided S3 will increase on inspiration whereas a left-sided S3 will increase on expiration. Duration: from 0.02 to 0.04 sec

![Figure 1 Timing of events in the cardiac cycle](image)

The rare fourth (atrial) heart sound when audible in an adult is called a **presystolic gallop** or **atrial gallop**. This gallop is produced by the sound of blood being forced into a stiff/hypertrophic ventricle. It is a sign of a pathologic state, usually a failing left ventricle, but can also be heard in other conditions such as restrictive cardiomyopathy. The sound occurs just after atrial contraction ("atrial kick") at the end of diastole and immediately before S1. An atrial heart sound can sometimes be recorded in the phonocardiogram, but it can almost never be heard with a stethoscope because of its weakness and very low frequency—usually 20 cycles/sec or less. This sound occurs when the atria contract, and presumably, it is caused by the inrush of blood into the ventricles, which initiates vibrations similar to those of the third heart sound. It is best heard at the cardiac apex with the patient in the left lateral decubitus position and holding his breath. It takes 0.05 to 0.10 sec to 0.02 to 0.04 sec after the P wave.

Listening to the sounds of the body, usually with the aid of a stethoscope, is called **auscultation**. The areas of the chest wall from which the different heart valvular sounds can
best be distinguished. The areas for listening to the different heart sounds are not directly over the valves themselves. The aortic area is upward along the aorta because of sound transmission up the aorta, and the pulmonic area is upward along the pulmonary artery. The tricuspid area is over the right ventricle, and the mitral area is over the apex of the left ventricle, which is the portion of the heart nearest the surface of the chest; the heart is rotated so that the remainder of the left ventricle lies more posteriorly.

**Phonocardiogram** is a graphic method of recording noises during his heart activity. Heart and vessels sounds are composed by audible and inaudible oscillations, but recordable. If a microphone specially designed to detect low-frequency sound is placed on the chest, the heart sounds can be amplified and recorded by a high-speed recording apparatus. Figure 2. Recording A is an example of normal heart sounds, showing the vibrations of the first, second, and third heart sounds and even the very weak atrial sound. Note specifically that the third and atrial heart sounds are each a very low rumble. The third heart sound can be recorded in only one third to one half of all people, and the atrial heart sound can be recorded in perhaps one fourth of all people.

![Figure 2 Phonocardiograms for normal(A) and abnormal heart sounds](image)

**Phonocardiogram in BIOPAC system**

Microphone or capsule stethoscope is placed in auscultation areas:
- mitral area: left fifth intercostals space, medial to left midclavicular line
- tricuspid area: left fourth intercostals space, lower left sterna border
- aortic area: right second intercostals space, right upper sterna border
- pulmonic area: left second intercostals space, left upper sterna border
- Erb area: left third intercostal space.
Experimental objectives:
1. To listen to human heart sounds (I and II) and describe them qualitatively in terms of intensity or loudness, pitch, and duration in mitral area.
2. To correlate the human heart sounds with the opening and closing of cardiac valves during the cardiac cycle and with systole and diastole of the ventricles.
3. The analysis of mechanical and electromechanical interval duration changes in of deep breathing and exercise conditions.

Materials
- BIOPAC Amplified Stethoscope (SS30L)
- BIOPAC electrode lead set (SS2L)
- BIOPAC disposable vinyl electrodes, 3 electrodes per Subject
- BIOPAC electrode gel (GEL1) and abrasive pad (ELPAD)
- Computer system
- BIOPAC data acquisition unit (MP36, MP35, or MP30 with cable and power)
**Principle**: recorded heart sounds with a stethoscope-microphone placed in the mitral auscultation area and analyzed in relation to the ECG; for the ECG is used D II derivation which is obtained by placing the negative electrode explorer right forearm (white cable), explorer positive the left leg (red cable) and right leg reference electrode (black cable).

Make sure the electrodes adhere securely to the skin. If they are being pulled up, you will not get a good ECG signal. The **Subject** must be relaxed during the calibration procedure. The
**Subject**’s arm needs to be relaxed so that the muscle (EMG) signal does not corrupt the ECG signal; he or she is in supine, physical and mental relaxation.

**Set Up**
1. Turn the computer **ON**.
2. Make sure the BIOPAC MP3X unit is turned **OFF**.
3. Plug the equipment in as follows:
   - Stethoscope (SS30L) — CH 3
   - Electrode lead set (SS2L) — CH 4
4. Turn the MP3X Data Acquisition Unit **ON**.
5. Select a **Subject**, a **Recorder** and, if appropriate in your lab group, a **Director**
6. **Start** the Biopac Student Lab Program.
7. Choose **Lesson 17 (L17-Hs-1)**.
8. **Type** in your filename
11. Click **OK**

**CALIBRATION**
Double check the electrodes, and make sure the **Subject** is relaxed.
Click on **Calibrate**. The **Calibrate** button is in the upper left corner of the **Setup** window. This will start the calibration recording. Read the prompt and click **OK**.
4. **Director** should lightly tap the stethoscope diaphragm twice. Wait for the calibration procedure to stop. **Check** the calibration data. At the end of the 8-sec calibration recording, the screen should resemble Figure 6. If similar, proceed to Data Recording. The **stethoscope** wave should have two clear spikes to indicate when it was lightly tapped. The **ECG** wave should not show any large spikes, jitter, or large baseline drifts.

![Figure 6](image)

If different, **Redo Calibration Recording**
You will note the heart sounds in mitral area and then record three segments: one with the **Subject** at rest, 5 cycles of deep breathing and one post-exercise. Two channels of data will be displayed during the recording: Stethoscope and ECG.

**Hints for obtaining optimal data:**
a) Apply the electrodes at least 5 minutes before recording. Sweating tends to affect electrode adhesion to the skin.
b) **Subject**’s clothing should not interfere with electrodes during the recording.
c) **Subject** should try to minimize EMG artifact generated in the arms and chest, which will interfere with the ECG signal. Do this by relaxing and not moving the right arm.
d) **Subject** should be at rest and should not have exercised within the last hour.
e) **Subject** should remain still and quite during the listening and recording segments. Any sound will be passed through the stethoscope.
f) **Director** should hold the stethoscope diaphragm with moderate and consistent pressure. Any change in pressure or movement will be picked up on the stethoscope as extraneous noise.

**DATA RECORDING**
Recording segments:
- segment 1 to 20 sec, normal breathing (sec 0-20)
- segment 2 to 20 sec, 5 cycles of deep breathing (20-40 sec)
- the third- 20 sec segment, one minute after exercise (40-60 sec)

Segment 1- at rest and deep breathing
When you click **Record**, the recording will begin and an append marker labeled “At Rest” will automatically be inserted. The **Subject** should breathe normally for the first 20 seconds. **Subject** should begin a slow, deep inhalation, hold for one second and continue with a slow exhalation, then return to normal breathing. Do not inhale quickly or deeply or you will increase the EMG artifact. **Recorder** should insert event markers and enter labels. To insert an event marker, press the **F9** key. Markers and labels may be edited after recording.

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**Data for Subject At Rest**
The heart sounds should be clearly visible and the ECG should not have excessive drift or noise.
**Segment 2: Post-exercise**
The **Subject** must be able to move about freely to exercise and elevate the heart rate. The **Subject** should know what it takes to elevate his/her heart rate. This will vary depending on the **Subject** and the level of physical fitness. Generally, doing 20-30 push-ups/jumping-jacks or running in place for 25-40 steps will suffice. Check electrode adhesion and reconnect cables after exercise. **Director** should place the stethoscope where it was placed for Segment
1. **Recorder** click **Resume**. When you click **Resume**, the recording will continue and an append marker labeled “Second recording with Subject recovering from moderate exercise” will be automatically inserted. Recorder click **Suspend** after 20 seconds of data has been recorded.

The ECG wave should not have excessive noise or drift. If it does, check electrode adhesion and redo the recording. When you click **Done**, you will be prompted to confirm that you are done with all recording segments. When you click **Yes**, a popup window with options will appear. Make your choice, and continue as directed. Remove the electrode cable pinch connectors, and peel off the electrodes. Throw out the electrodes (BIOPAC electrodes are not reusable). Wash the electrode gel residue from the skin, using soap and water. The electrodes may leave a slight ring on the skin for a few hours. This is normal, and does not indicate that anything is wrong.

**Data Analysis**

Enter the **Review Saved Data** mode.

The analysis is based on the selection of areas with the cursor and reading parameters. Set up the measurement boxes as follows:

*Channel Measurement*  
**CH 3 p-p**  
**CH 3 ΔT**
CH 3 BPM

The following is a brief description of these specific measurements.

**P-P** shows the difference between the maximum amplitude value and the minimum amplitude value in the selected area.

**ΔT (delta time)** is the difference in time between the end and beginning of the selected area. **Beats Per Minute** calculates the difference in time between the first and last selected points and then divides this value into 60 seconds/minute to extrapolate **BPM**.

**Zoom** in on an area of two complete cardiac cycles. **Zoom** to an area when the **Subject** was breathing normally, before the start of deep inhalation. Using the **I-Beam** cursor, select the area from one R-wave to the next R-wave. Note the **BPM** measurement.

**Zoom** in on an area of one complete cardiac cycle. **Note:** Make sure the cardiac cycle you select does not have extraneous noise. Using the **I-Beam** cursor, select an area from the start of one R-wave to the first peak of the first heart sound. Note the **ΔT** measurement. Using the **I-Beam** cursor, select an area from the start of one R-wave to the first peak of the second heart sound. Note the **ΔT** measurement.

Using the **I-Beam** cursor, select an area from the start of the second heart sound to the start of the first sound of the next cycle. Note the **ΔT** measurement.

Using the **I-Beam** cursor, select an area that encompasses the first heart sound. Note the **p-p** measurement.

Using the **I-Beam** cursor, select an area that encompasses the second heart sound. Note the **p-p** measurement.

Scroll to the **Inhale** interval of the “At Rest” segment of the recording and take the measurements described above as required to complete Table. Scroll to the **Exhale** interval of the “At Rest” segment of the recording and take the measurements described above as required to complete Table.

Scroll to the **Post-exercise** segment of the recording and take the measurements described above as required to complete Table.

You may save the data to a drive, save notes that are in the journal, or print the data file.

**DATA REPORT**

**Student’s Name:**
**Lab Section:**
**Date:**

**I. Data and Calculations**

**Subject Profile**

Name ..........................................................Height
Age.......................... Weight..........................
Gender: Male / Female

**A. Heart Sound Measurements**

Complete Table with **Segment 1** and **Segment 2** data and complete the required calculations.
<table>
<thead>
<tr>
<th>Measurement</th>
<th>CH #</th>
<th>Segment 1</th>
<th>Segment 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>At Rest</td>
<td>Inhalation</td>
</tr>
<tr>
<td>BPM</td>
<td>CH 3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ΔT R-wave to first sound</td>
<td>CH 3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ΔT R-wave to second sound</td>
<td>CH 3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ΔT first to second calculate</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ΔT second sound to next first sound</td>
<td>CH 3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>p-p first sound</td>
<td>CH 3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>p-p second sound</td>
<td>CH 3</td>
<td></td>
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</tr>
</tbody>
</table>
Advantages of registration phonocardiogram:
- are presented not hear noise
- allows the progress of heart breaths
- appreciate the severity of valve lesions.