ELEC S421F Biomedical Informatics

Lab Session: ***BIOPAC Student Lab Session 5: ECG - I***

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Student Number: 12399068

Group Number: 3

Aims:

- Describe how ECG is used as a tool for evaluating electrical events within the heart.
- Outline the procedures for performing a one-lead ECG recording.
- Correlate electrical events as displayed on the ECG with the mechanical events that occur during the cardiac cycle; and
- Describe rate and rhythm changes in the ECG associated with exercise and breathing.

Equipment & Materials:

- Printed materials:
    - Biopac Student Lab Lesson 5: Electrocardiography (ECG) I – Introduction
    - Biopac Student Lab Lesson 5: Electrocardiography (ECG) I – Procedure
- Mat and pillow for measurement in supine position
- The following parts from Biopac Student Lab Advanced System:
    - MP36 Data Acquisition Unit with USB Cable, DC Adapter, and power cord
    - Biopac Electrode Lead Set (SS2LB) x 1
    - Biopac Disposable Electrodes (EL503) x 3
- Computer installed with Biopac Student Lab (BSL) 4 Software

Procedure:

A. **Setup**

1. Turn the computer ON and turn OFF the MP36 unit
2. Plug the Electrode Lead Set (SS2L) to CH1
3. Using the alcohol wipe provided, clean and abrade skin at the electrode placement sites.
4. Attach three electrodes on Human Subject
5. Clip the Electrode Lead Set (SS2L) to the electrodes.

   WHITE Lead – RIGHT forearm

   BLACK lead (ground) – RIGHT leg

   RED lead – LEFT leg
6. Subject gets in supine position (lying down, face up) and relaxes (Fig. 1)

Fig. 1 Positioning (supine)

7. Start the BIOPAC Student Lab program
8. Choose Lesson L05-ECG-1 then click OK. Type in filename and click OK.

B. **Calibration**

1. Subject is spine and relaxed, with eyes closed
2. Click Calibrate. Make sure the subject remains relaxed with eyes closed and wait for Calibration to stop
3. Verify recording resembles example data. If similar, click Continue and proceed to Data Recording. If necessary, click Redo Calibration.

C. **Data Recording**

1. **Supine**
   - Subject remains relaxed with eyes closed.
   - Click **Record** and wait for 20 seconds.
   - Click Suspend
   - Verify recording resembles the example.

Fig. 2. Supine data

2. **Seated**
   - Subject gets up quickly and then settles into a seated position
   - Once Subject is seated and still, click **Record.** Record for 20 seconds.
   - Click Suspend
   - Verify recording resembles the example.

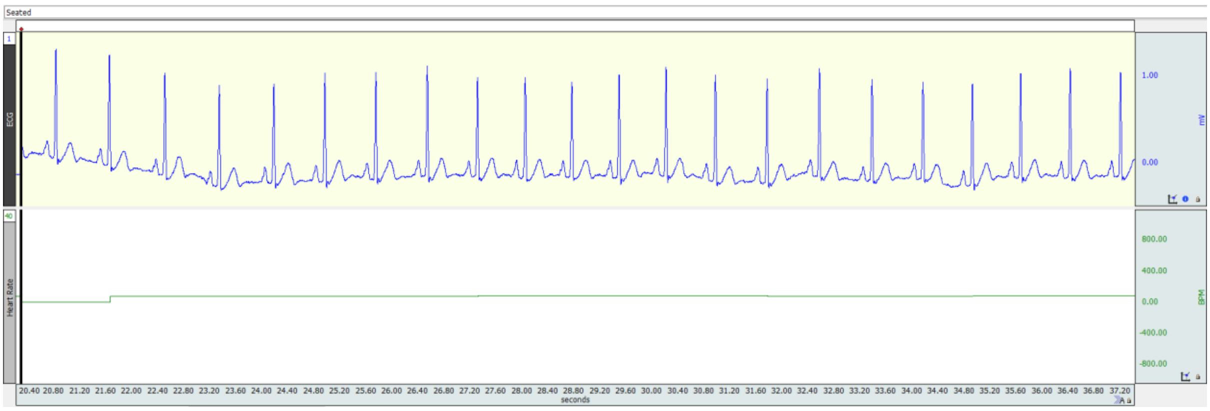


Fig. 3. Seated data

3. **Deep Breathing**
   - Click **Record**

- Subject inhales and exhales slowly and completely as possible for five prolonged (slow) breath cycle. Press F4 at the start of each inhale. Press F5 at the start of each exhale.
- Click Suspend
- Verify recording resembles the example.

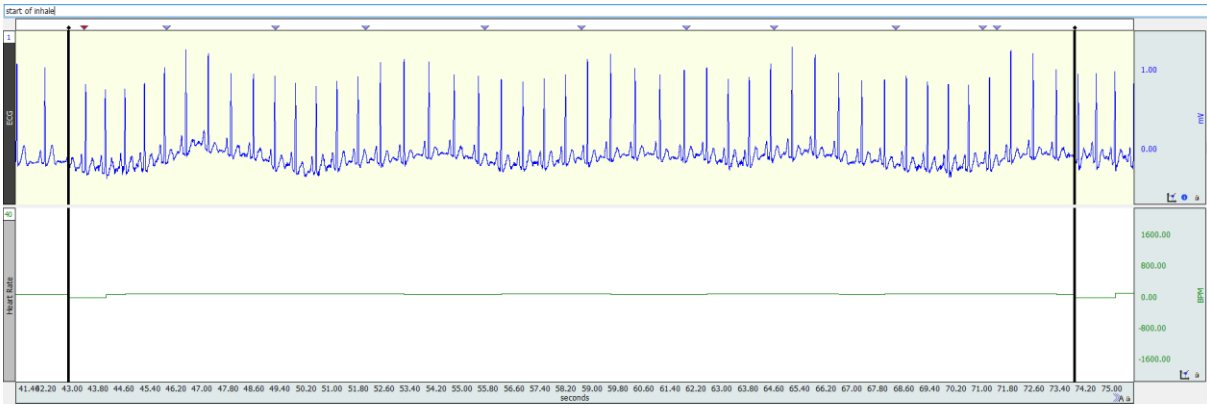


Fig. 4. Deep Breathing data

4. After exercise

- Subject exercises to elevate heart rate
- Subject sits down and relax
- **Record** for 60 seconds
- Click Suspend
- Verify recording resembles the example.

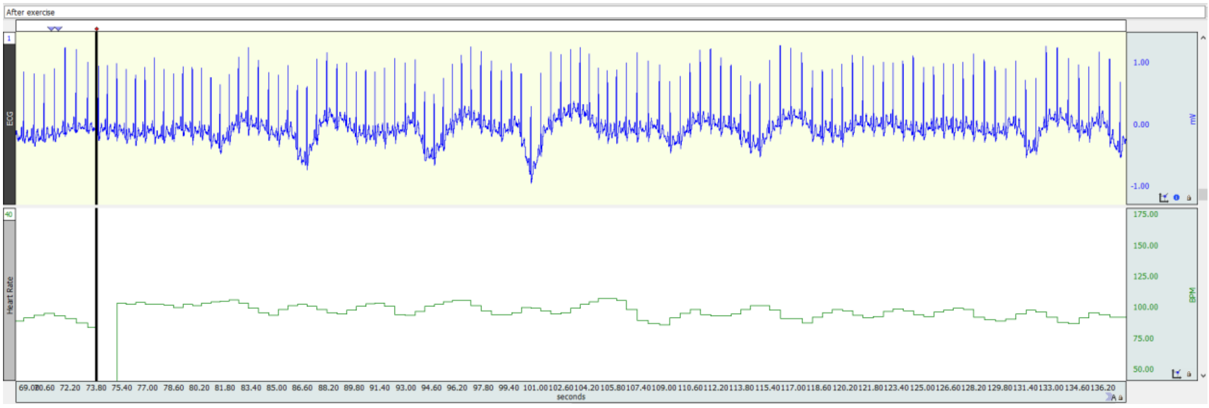


Fig. 5. After exercise data

Results:

DATA REPORT

Student's Name: Zhang Hanhao

Lab Section: BIOPAC Student Lab Session 5: ECG - I

Date: 30 Sep 2022

I. Data and Calculations

Subject Profile

Name: Zhuang Weihao Height: 1.74 m

Age: 24 Gender: Male / ~~Female~~ Weight: 69 kg

A. Heart Rate

Complete the following tables with the lesson data indicated, and calculate the Mean as appropriate;

Table 5.2

Recording: Condition	Cardiac Cycle [40] [Value] 1	2	3	Mean (calculate)
Supine	75.27384	74.34944	70.92198	73.5150867
Seated	76.33587	82.53094	80.86253	79.90978
Start of inhale	87.08272	79.68127	80.42895	82.2376467
Start of exhale	92.02453	91.46341	90.77155	91.41983
After exercise	105.07880	94.93670	98.52216	99.5125533

- If CH 40 was not recorded, use [1] [BPM].

B. Ventricular Systole and Diastole

Table 5.3

Condition	Duration (ms) [1] [Delta T]	
	Ventricular Systole	Ventricular Diastole
Supine	285	558
After exercise	245	443

C. Components of the ECG

Table 5.4

Condition: Supine Recording (measurements taken from 3 cardiac cycles)

ECG Component	Normative Values Based on resting heart rate 75 BPM		Duration (ms) [1] [Delta T]				Amplitude (mV) [1] [P-P]			
			1	2	3	Mean (calc)	1	2	3	Mean (calc)
Waves	Dur. (sec)	Amp. (mV)								
P	.07 - .18	< .20	119	112	125	118.6	0.15899	0.16296	0.17059	0.16418
QRS Complex	.06 - .12	.10 – 1.5	104	95	99	99.3	1.36199	1.29425	1.30920	1.321813
T	.10 - .25	< .5	233	256	251	246.7	0.29876	0.35217	0.30364	0.31819
Intervals	Duration (seconds)									
P-R	.12 - .20		108	168	144	140				
Q-T	.32 - .36		337	356	350	347.6				
R-R	.80		809	812	811	810.6				
Segments	Duration (seconds)									
P-R	.02 - .10		63	73	67	67.7				
S-T	< .20		71	65	53	63				
T-P	0 - .40		300	301	299	300				

Table 5.5

Condition: After Exercise Recording (measurements taken from 1 cardiac cycle)				
ECG Component	**Normative Values** Based on resting heart rate 75 BPM		**Duration (ms)** 1 Delta T	**Amplitude (mV)** 1 P-P
Waves	Dur. (sec)	Amp. (mV)		
P	.07 - .18	< .20	117	0.23284
QRS Complex	.06 - .12	.10 – 1.5	97	1.19110
T	.10 - .25	< .5	204	0.17669
Intervals	Duration (seconds)			
P-R	.12 - .20		115	
Q-T	.32 - .36		107	
R-R	.80		600	
Segments	Duration (seconds)			
P-R	.02 - .10		20	
S-T	< .20		17	
T-P	0 - .40		133	

Note Interpreting ECGs is a skill that requires practice to distinguish between normal variation and those arising from medical conditions. Do not be alarmed if your ECG does not match the "Normative Values."

II. Questions

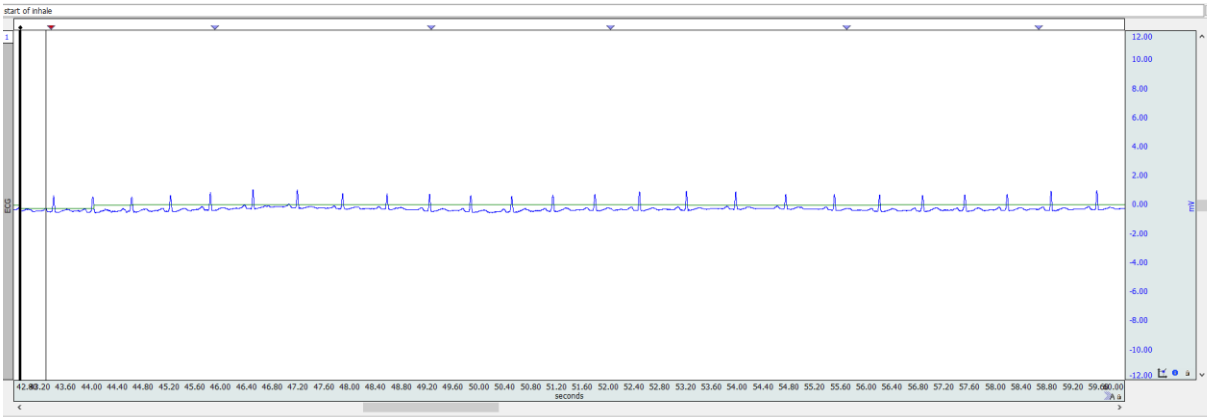
D. Using data from table 5.2:

1) Explain the changes in heart rate between conditions. Describe the physiological mechanisms causing these changes.

Supine heart rate presents the resting heart rate, which is the lowest heart rate. When the subject get up and sit in chair, the heart rate increases slightly. Antigravity muscle activity influences vasomotor and cardiovascular activity during postural change. The sitting posture minimized antigravity muscle involvement. [1] During inhalation period, heat rate increases because the momentary drop in systemic arterial blood pressure during inspiration reduces the frequency of carotid baroreceptor firing, causing a momentary increase in heart rate. Exhalation let heat rate decrease because systemic venous baroreceptors increases cardiac output and systemic arterial blood pressure, which increases carotid baroreceptor firing causing heart rate to decrease. The subject's heat rate increase as exercise stimulate sympathetic. Therefore, the subject breathe more frequency to deliver more oxygen and nutrients to muscles

2) Are there differences in the cardiac cycle with the respiratory cycle ("Start of inhale-exhale" data)?

Yes. A respiratory cycle consists of one inhalation followed by an exhalation. As the data and figure shown below, one respiratory cycle may contain nine cardiac cycles.



E. Using data from table 5.3:

1) What changes occurred in the duration of systole and diastole between resting and post-exercise?

The duration of systole and diastole after exercise get shorter because the body need more energy and blood to support, thus cardiac beats more frequency, the systole and diastole duration value become smaller comparing to supine condition.

F. Using data from tables 5.4 and 5.5:

1) Compared to the resting state, do the durations of the ECG intervals and segments decrease during exercise?

Explain Yes. Q-T interval and Segments decrease sharply. Exercise stimulate sympathetic. The body requires a lot of oxygen for energy (ATP) production and blood. Cardiac contract will be increased.

2) Compare your ECG data to the normative values. Explain any differences.

There's no abnormal values but the QRS complex duration in supine recording is approaching the limit of normal values. The reason might be the Q wave is not clearly enough to be observed. The Q wave is completely on the isoelectric line. This makes it impossible to accurately determine the start of QRS complex.

3) Compare ECG data with other groups in your laboratory. Does the data differ? Explain why this may not be unusual.

Yes. Because the research samples are different in weight, height, age, and gender. Some of individuals may have long-term physical training. Those (usually) have larger and efficient heats, theirs ECGS may exhibit differences other than average.

G. In order to beat, the heart needs three types of cells. Describe the cells and their function.

1) Rhythm generators, which produce an electrical signal (SA node or normal pacemaker)
2) Conductors, to spread the peacemaker
3) Contractile cells (myocardium) to mechanically pump blood.

H. List in proper sequence, starting with the normal pacemaker, elements of the cardiac conduction system.

1) Normal pacemaker
2) Sinoatrial node (SA node)
3) Internodal pathways
4) Atrial fibers
5) Atrioventricular node (AV node)
6) Bundle of His
7) Bundle branches
8) Purkinje fibers

I. Describe three cardiac effects of increased sympathetic activity, and of increased parasympathetic activity.

Sympathetic The sympathetic division increases automaticity and excitability of the SA node, thereby increasing heart rate. It also increases conductivity of electrical impulses through the atrioventricular conduction system and increases the force of atrioventricular contraction.

Parasympathetic

The parasympathetic division decreases automaticity and excitability of the SA node, thereby decreasing heart rate. It also decreases conductivity of electrical impulses through the atrioventricular conduction system and decreases the force of atrioventricular contraction. Parasympathetic influence increases during exhalation.

J. In the normal cardiac cycle, the atria contract before the ventricles. Where is this fact represented in the ECG?

P wave represents cardiac systole

QRS complex represents cardiac diastole

K. What is meant by "AV delay" and what purpose does the delay serve?

The SA node impulse also spreads to the atrioventricular node (AV node), the electrical signal is delayed in the AV node for approximately 0.20 seconds when the atria contract. The wave of depolarization does not spread to the ventricles right away because there is nonconducting tissue separating the atria and ventricles.

L. What is the isoelectric line of the ECG?

The isoelectric line is a point of departure of the electrical activity of depolarizations and repolarizations of the cardiac cycles and indicates periods when the ECG electrodes did not detect electrical activity

M. Which components of the ECG are normally measured along the isoelectric line?

The Segments are normally measured along the isoelectric line.

Discussion:

During ECG analysis period, it is easy to find ECG signals are corrupted by noise. A brief description of predominant noises in ECG includes baseline wander (BW), power line interference (PLI), muscle artefact (MA or EMG) and instrumentation noise (IN). [2]

As the figure 6 shown below, BW noise is particularly obvious during and after exercise. The baseline (x - axis) of ECG signal drift up and down rather than be straight. And in frequency aspect, the typical frequency of baseline wander in range of 0.5 Hz. The baseline wander is caused due to improper electrodes (electrode-skin impedance), patient's movement and breathing (respiration). [3] To remove baseline wander from ECG signal, use a high pass filter with 0.5 Hz cut-off frequency which can filter out signal component with frequency below 0.5 Hz while frequency above 0.5 Hz are preserved. [4]

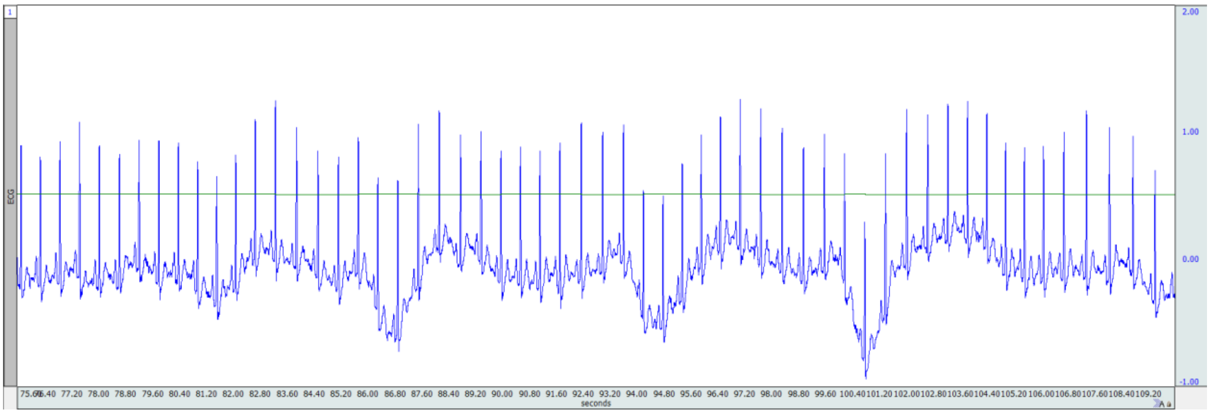


Fig. 6 ECG signal with baseline wander

PLI is a major a major source of noise in the ECG signal which consists of 60 Hz pickup (in the U.S.) and harmonics. [5][6] Since PLI is not constant, the subtraction procedure is applied originally with sampling frequency f_S, a multiple of, and hardware synchronized with the PL frequency f_{PL}. The procedure consists of the following steps. [7]

- ECG segments with frequency band near zero are continuously detected using an appropriate criterion. They are referred to as linear segments and are found mainly in the PQ and TP intervals, but also in sufficiently long straight parts of the R and T waves.
- The samples of these segments are moving averaged, i.e., subjected to a linear phase comb filter [8] with first zero set at f_{PL}. Thus, the filtered samples do not contain interference.
- Interference amplitudes, called corrections, are calculated for each of the phase-locked samples, n, in the PL period, T_{PL}, by subtracting the filtered samples from the corresponding ones of the contaminated (original) ECG signal.
- The set of corrections obtained is continually updated in linear segments and used in non-linear segments (usually around QRS complexes and high-amplitude T waves) to subtract the interference from the original ECG signal.

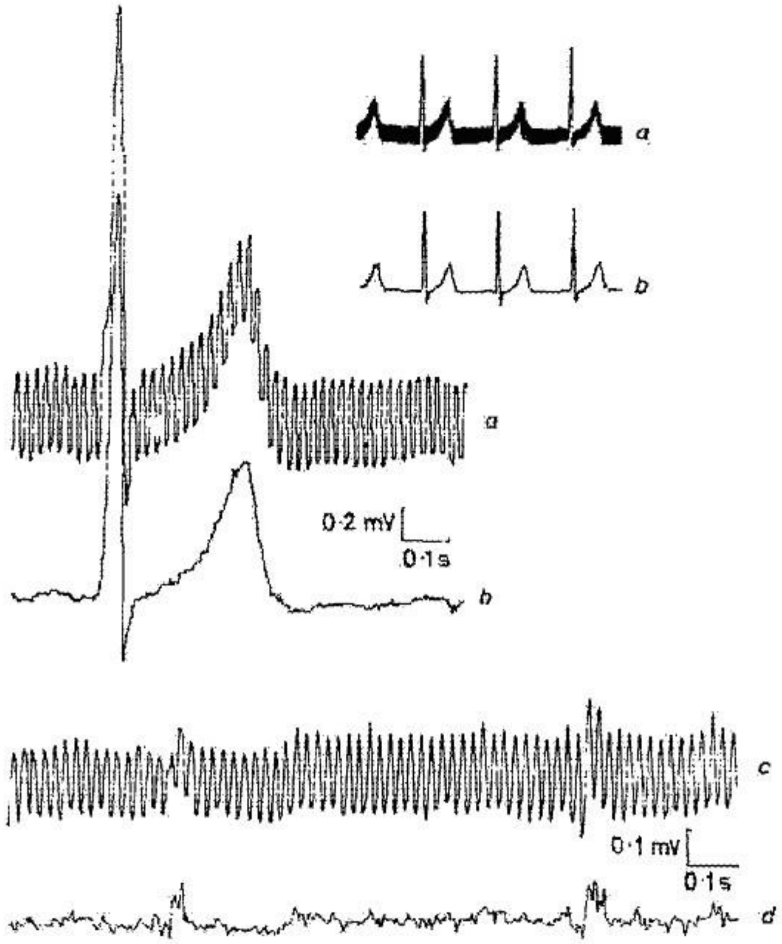


Fig.7. One of the first results obtained by the subtraction procedure. [9]

The muscle artifacts are caused by the electrical activity of muscles during periods of contraction or due to a sudden body movement.[10] The most common approach to reduce muscle artifacts in electroencephalographic signals is to linearly decompose the signals in order to separate artifactual from neural sources, using one of several variants of independent component analysis (ICA).[11] And instrumentation noise is induced in ECG signals when they are transmitted through a channel with poor channel conditions.

Before performing experiments, the experiment subject is better to remove all jewelry from the neck, arm, and wrists. If the patient feel uncomfortable due to hitting by foreign objects in the clothing during the experiments, it will affect the test results. The subject also has obligations to provide what medications are taking if any and whether there was an allergic to the tape that can be used to attach the electrodes. During the exercise ECG test, subjects should also be told to stop if feeling uncomfortable.

There are many ethical issues should be considered before or during the experiments such as many users don’t want to get ECG recording because of privacy concerns. Gender, age, height, and weight are required to be provided before experiments, which may be considered disrespectful. Some patients would view the wrist electrodes device as minimally invasive. Also, the patient may choose to ignore the measurements sent as a result of not trusting the ‘simply’ device.

Biopac Student Lab (BSL) is a great application that covers serval tutorial videos and the corresponding lessons. Analyzing lesson data is provided by this tool as well. Users can follow the given steps to evaluate electrical events.

Conclusion:

Through roughly measuring the duration and amplitude of ECG components, the values obtained from this experiment are all within the normal range. However, analyzing ECG event from pure data via BSL is actually unfeasible as it is still necessary to manually divide the ECG components' boundaries, and the errors generated in this will definitely have a great impact on the statistics. Besides it, the noise cannot be ignored either. Therefore, to measure a more accurate wrist ECG signal, performing ECG signal processing after this experiment is an indispensable section.

Appendix

[1] Watanabe, J. Reece, and B. I. Polus, “Effects of body position on autonomic regulation of cardiovascular function in young, healthy adults,” *Chiropractic & Osteopathy*, vol. 15, no. 1, 2007.

[2] P. Kumar and V. K. Sharma, “Detection and classification of ECG noises using decomposition on mixed codebook for quality analysis,” *Healthcare Technology Letters*, vol. 7, no. 1, pp. 18–24, 2020.

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[4] A. Jayant, T. Singh and M. Kaur (2013): Different Techniques to Remove Baseline Wander from ECG Signal, Int. J. of Emerging Research in Management & Technology, 2.

[5] G. M. Friesen, T. C. Jannett, M. A. Jadallah, S. L. Yates, S. R. Quint and H. T. Nagle, "A comparison of the noise sensitivity of nine QRS detection algorithms," in IEEE Transactions on Biomedical Engineering, vol. 37, no. 1, pp. 85-98, Jan. 1990, doi: 10.1109/10.43620

[6] T. Sharma and K. K. Sharma, "Power line interference removal from ECG signals using wavelet transform based component-retrieval," 2016 International Conference on Advances in Computing, Communications and Informatics (ICACCI), 2016, pp. 95-101, doi: 10.1109/ICACCI.2016.7732031.

[7] Levkov C, Michov G, Ivanov R, Daskalov I: Subtraction of 50 Hz interference from the electrocardiogram. *Med Biol Eng Comput* 1984, 22: 371–373.

[8] McManus CD, Neuber KD, Cramer E: Characterization and elimination of AC noise i electrocardiograms: a comparison of digital filterimg methods. *Comput Biomed Res* 1993, 26: 48–67.

[9] C. Levkov, G. Mihov, R. Ivanov, I. Daskalov, I. Christov, and I. Dotsinsky, “Removal of power-line interference from the ECG: A review of the subtraction procedure,” BioMedical Engineering OnLine, vol. 4, no. 1, 2005

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