

RESEARCH ARTICLE

## Impact of Stress and Radiation of Cellular Phones on Heart and its Functions

\*Ali Hussein Faraj Alnasraui<sup>1</sup>

<sup>1</sup>College of Biotechnology, Al -Qasim Green University, Babelon, Iraq.

Received-03 February 2016, Revised-1 March 2016, Accepted-24 March 2016, Published-28 March 2016

### ABSTRACT

The furious rate of technological change and growth in mobile products has made it very popular for users to get occupied in these devices. Smartphone revolution has made the users to use cellular phones more frequently which often results in stress factors causing severe impact over brain cells and heart functions. This article deals with the stress affecting heart. The research was conducted on a group of students under normal and vibration modes of mobile phones. Different types of phone modes and the stress generated by them which affects the heart are analysed. It is noted that human heart is sensitive to stress generated by Electromagnetic Fields (EMF) emitted from cellular phones in normal mode rather any other modes resulting in drastic changes of heart rate. Strong artificial EMFs can enter the body and interfere with the natural way the body works. This can affect virtually any system within the body from stress levels to DNA. The investigations are done by an electrocardiogram unit which depicts the Heart Rate Variability (HRV) i.e., the fluctuations in the heart rate from the average heart rate. HRV is regulated by the autonomous nervous system which decreases as the heart rate increases. The variation in heart rate is determined by means of ECG which records the electrical activity of the heart. Based on the results, significant analysis of stress recovery factors is performed.

**Keywords:** Technological development, Smartphone revolution, Electromagnetic field, Stress, Heart rate variability.

### 1. INTRODUCTION

Stress is the response to the demands of everyday life. This can be useful to certain extents. For example in completing ones task on a regular basis so that it keeps a person active. But when the stress level reaches an extreme condition, the situation may result in total disorder. It can affect heart and its functions resulting in high blood pressure, cerebrovascular accident (stroke), lowered immunity response, weight loss, depression and malfunctioning of internal organs. The body responds to stress and anxiety in the same way as it responds to fear and excitement. Stress is caused by work pressure, lack of confidence, unrealistic expectations, chronic illness, longer hours of work, etc. Overuse of mobile phones also results in stress which is one of the main reasons in the present environment. The heart rate, which is the speed of the heart beat measured by the number of

contractions of the heart, is varied according to the body's physical needs, including the need to absorb oxygen and excrete carbon dioxide. It is usually equal or close to the pulse measured at any peripheral point. Activities that can provoke changes include physical exercise, sleep, anxiety, stress, illness and ingestion of drugs, where stress is the leading factor affecting the functioning of the heart directly. EMFs either pass through the heart without interaction or they interact directly. Static and time-varying fields interact with the body differently. Extremely low frequency (ELF) EMFs easily penetrate tissues and cause virtually non-sensory reactions. The reaction of the cardiovascular system to ELF EMFs is complex and includes direct responses of cardiac muscles. High frequency and high strength EMFs undoubtedly affect the cardiovascular system. It is important to evaluate whether the extensive use of mobile

\*Corresponding author. Tel.: +9647723965694

Email address: [alinalnasraui@gmail.com](mailto:alinalnasraui@gmail.com) (A.H.F.Alnasraui)

Double blind peer review under responsibility of DJ Publications

<http://dx.doi.org/10.18831/djece.org/2016021001>

2455-3980 © 2016 DJ Publications by Dedicated Juncture Researcher's Association. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

phones in various types of jobs could exert influence on heart. The cellular stress response is a reaction to potentially harmful stimuli in the environment.

EMF stimulates protein synthesis and affects the two strands of DNA. Since EMF can interact with DNA, it can cause errors during replication. During protein synthesis higher energy EMF causes DNA strand breaks, which keeps the cells in stressed condition. This condition of stress due to the exposure of electromagnetic and infra-red effects of cellular phones affecting heart and its working is analysed and explained.

## **2. LITERATURE SURVEY**

[1] Electroencephalogram (EEG) recording changes due to the exposure of GSM phone in teenagers. Cellular phones may reversibly influence the human brain and produces serious effect on the cognitive functions in children. Three physiological variables namely heart rate, respiration rate and heart rate variability are selected to assess the activity of the autonomous nervous system. [2] Electromagnetic radiation has been increased due to the increase in use of communication devices which affects reproductive functions and membrane oxidative mechanism in human beings. The oxidative stress from exposure to Wi-Fi and mobile phone induced EMR affects the functioning of heart. [3] Owing to excessive usage of smart phones, this study has outlined several health related issues like increasing stress among the users, sleeplessness, cervical problems, memory loss, hearing inability thus leading to abnormal heart functions. [4] Certain portion of the heart muscle gets thickened creating functional impairment of the cardiac muscle leading to sudden cardiac death. This condition occurred as a result of stress involving different signalling pathways in the cardiac system. [5] The death of heart muscle occurs due to unusual enlargement of tissues or cells and restriction of blood supply to certain parts of muscle as a result of cellular waves or oxidative stress. Any damage to cells is constantly repaired. However under severe levels of stress it may lead to death of almost all the cells in the organ. The damage causes lack of energy transfer within cells depletion, preventing controlled death and causing the cell to fall apart. [6] Electromagnetic fields emitted by mobile phone base stations affect

the well behaviour of humans. In certain conditions, it may not have serious impact on heart functions directly but it may result in adverse effects. [7] The health effects on the exposure to mobile phone base station radiation is reviewed and evaluated by conducting systematic review of randomized human trials in the laboratory. Based on the experiments, it is concluded that though there are no acute disorders resulting due to the exposure of mobile phone radiation, mild defects occurred in children and adolescents. Evidence for the absence of long-term effects is limited. [8] Exposure to high levels of electromagnetic radiation leads to cardiovascular diseases. This systematic review evaluates the changes in Heart Rate Variability (HRV) due to stress from various sources. Hence parasympathetic nervous system activity should be focused to protect cardiovascular health on stress related issues. The use of very low and ultralow frequency HRV components in autonomic research is proposed. Significant increase in arterial blood pressure correlates with the exposure level. [9] Certain illness arises spontaneously for which the cause is unknown but believed to be EMF. It is suggested that EMF is not the main cause for such illness. Further revised study states that overdose of stress due to mobile exposure causes disturbance to the working of the heart by varying the pressure levels of the arterial valves. [10] The emission of low level radio frequency electromagnetic fields leading to the absorption of radiation by the brain in users of handheld mobile phones has raised concerns regarding potential effects on health. A systematic review of studies of controlled exposure to radio frequency radiation with health-related outcomes (electroencephalogram, cognitive or cardiovascular function, hormone levels, symptoms and subjective well-being) is conducted. Health-related outcomes include electroencephalogram (EEG) recordings, assessments of cognitive or cardiovascular function, hormone levels and subjective well-being and symptoms. [11] The perception of electromagnetic radiation and Infra-Red (IR) reports shows the health facts. These consequences cannot be detected accurately unless a series of research is performed. When individuals with self-reported electromagnetic hypersensitivity are exposed to EMF, their well behaviour is affected as a result of long

term use of those devices. There are established basic mechanisms through which static and time-varying electric and magnetic fields interact directly with living matter. Induced time-varying fields can stimulate excitable cells such as cardiac muscles. [12] Changes in heart rate variability during a call using mobile phone are a result of electromagnetic field. The electromagnetic energy produced by cellular telephones may reach very high values of power density during logging into the telephone network or at the starting stage in order to eliminate extreme conditions. The study was performed at a place with a stable high network signal and after the mobile phone was logged into the network. This possibility should be taken into account while HRV analysis is performed without simultaneous acquisition and analysis of respiration. [13] The experimental results showed a significant effect of telephoning while driving as opposed to normal driving. The subjects who operated the hands free telephone showed better control over the test vehicle than the subjects who operated the handheld telephone, as measured by the steering wheel movements. A clear improvement over time was found for some of the measurements as a consequence of the results, which clearly depicts the ill-facts regarding the stress developed while driving, owing to the use of mobile phones. [14] Based on stress associated with electromagnetic field exposure, several heart related symptoms and other problems are reported. These symptoms may be related to specific EMF sources or to electrical equipment in perceived electromagnetic hypersensitivity. Research and clinical observations suggest a difference between mobile phone related symptoms with respect to symptom prevalence, psychological factors and health prognosis. This study assessed prevalence of EMF-related and EMF-nonrelated symptoms like anxiety, depression, somatization, exhaustion and stress in people using mobile phone. [15, 16] While conducting studies with EMF, the participants in the research experienced severe headache and had other symptoms of cardiac disorder. They also specified the maximum degree of symptoms during exposure. The degree of headache and other symptoms are indicated on a two 100-mm Visual Analogue Scales (VAS). Electromagnetic fields from mobile phones induce alterations in the brain's blood flow.

Electroencephalographic wave pattern during rest (awake and sleep) state are excited to transcranial magnetic stimulation.

### 3. CARDIAC CONDUCTION SYSTEM AND ITS CORRELATION WITH ECG

The heart is able to create its own rhythm and it conducts signals necessary to maintain and coordinate the rhythm.

The conduction system shown in figure 1, starts with the Sino-Atrial (SA) node which is responsible for setting the pace of the heart as a whole and directs the atria to contract. The signal from the SA node is collected by the Atrio-Ventricular (AV) node and transmits it through the Atrio-Ventricular (AV) bundle. Branches from the left and right bundle are known as Purkinje fibres that carry the signal to the walls of the ventricles, stimulating the cardiac muscle cells to contract thereby pump blood out of the heart.

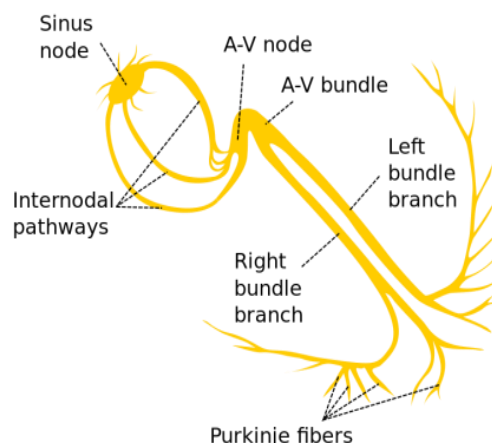


Figure 1. Cardiac conduction system

Electrocardiography is the process of recording the electrical activity of the heart using electrodes placed on the skin. These electrodes detect any electrical changes on the skin from the heart muscle depolarizing during each heartbeat. When the electrical impulse passes through the heart, electrical current is created that spread through the body and reaches the surface of the skin. These impulses cannot be realised but can be picked up and graphed as an electrocardiogram, which is simply a recording of the flow of the electrical current through the heart. This is a common test used to detect problems in the heart. The overall magnitude and direction of the electrical depolarization is captured at each moment throughout the cardiac cycle.

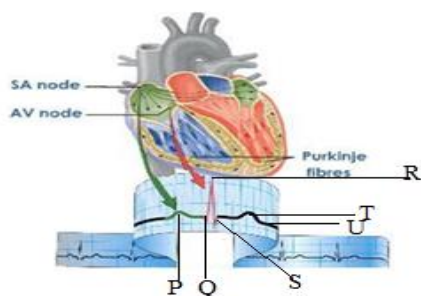


Figure 2. Normal ECG pattern

The impulse of the heart contraction originates in the SA node. It consists of cardiac fibres, myofibrils and nerve endings from autonomous nervous systems. Electrical impulse generated from the SA node causes the heart to contract. Although the electrical impulses are generated spontaneously, the heart rate is set by the nerves innervating the SA node. During the ventricular contraction, the Purkinje fibres carry the contraction impulse from both the left and right bundle branch to the myocardium of the ventricles. This causes the muscle tissue of the ventricles to contract and generate force to eject blood out of the heart.

AV receives impulse from the SA node and transmits it to the ventricles. The SA node on the wall of the right atrium initiates depolarization in the right and left atria causing contraction, which is symbolized by the P wave on an electrocardiogram. The SA node sends the depolarization wave to the AV node causing contraction in both ventricles represented by the QRS wave. The ventricles are re-polarized and relaxed denoted by the T wave. U wave is often ignored (figure 2).

### 3.1. ECG

The block diagram of ECG device is given in figure B1. The potentials picked up by the patient electrodes are taken to the lead selector switch. The electrodes are selected according to the lead program. The signal is then given to the preamplifier which prepares the electronic signal for further amplification or processing. It is usually a 3 or 4 stage differential amplifier. The amplified output is fed to the power amplifier. The output of the power amplifier is supplied to the pen motor which deflects the writing arm of the paper. Frequency selective network is an R-C network, which provides necessary damping of the pen. The auxiliary circuits provide 1 mV

calibration signal and automatic blocking of the amplifier during the changes in the position of the lead switch. It also includes a speed control circuit for the chart driver motor.

## 4. METHODOLOGIES

The experiment is conducted for finding the effect of different modes of phone on heart rate using ECG in a group of five Indian students. ECG machine named Cardiart 108T Digi and jelly based Silver-Silver Chloride specialized exclusively for ECG are used in this experiment. It uses four limb electrodes for both hands and legs and one electrode for chest. i.e. suction cup electrode.

CARDIART 108T-DIGI comes with real time high fidelity thermal array recording. This Single Channel ECG Recorder has sharp and clear trace with electronic lead selection and easy operation.

The ECG works by detecting and amplifying the tiny electrical changes on the skin that are caused when the heart muscle depolarises during each heartbeat. At rest, each heart muscle cell has a charge across its outer wall or cell membrane. Reducing this charge towards zero is called de-polarization, which activates the mechanisms in the cell that causes it to contract. During each heartbeat a healthy heart will have an orderly progression of a wave of depolarisation that is triggered by the cells in the SA node, spreads out through the atrium, passes through intrinsic conduction pathways and then spreads all over the ventricles. This is detected as rise and fall in the voltage between two electrodes placed on either side of the heart which is displayed as a wavy line either on a screen or on a paper. This display indicates the overall rhythm of the heart and weaknesses in different parts of the heart muscle. In case if the heart is affected and stressed due to electromagnetic waves, the ECG readings would not be normal and further proceedings are analysed.

### 4.1. ECG Procedure

Prior to ECG proceedings, it is necessary to ensure if the body is in normal condition and hence blood pressure is checked. The required pulses are recorded over both hands and legs. ECG is recorded while placing the limb electrodes on the hands and legs, while one suction cup electrode is placed on chest near the SA node of the heart and thereby the waveforms are analysed by applying ECG

jelly which is a water soluble saline based gel that promotes electrical conductivity.

Electrode is a conductive pad in contact with the body that makes an electrical circuit with the electrocardiograph. On a standard 12-lead ECG there are 10 electrodes. Leads are divided into three sets namely, limb, augmented limb and precordial leads. The 12-lead ECG has three limb leads, three augmented limb leads and six precordial leads. Limb and precordial leads are bipolar and unipolar respectively.

**5. RESULT ANALYSIS**

Five Indian students were subjected to this research and heart rate recordings were taken in normal and vibration + ring modes and analysed accordingly.

The heart rate analysis of Avenash in normal and vibration + ring condition is provided in table A1 and A2

1) Name: Avenash  
Age: 21 yrs.  
Sex: Male

The pulse rate in normal and vibration + ring condition is 64.85 and 70 respectively.

The heart rate analysis of Sachen in normal and vibration + ring condition is provided in table A3 and A4

2) Name: Sachen  
Age: 20 yrs.  
Sex: Male

The pulse rate in normal and vibration + ring condition is 67.78 and 74 respectively.

The heart rate analysis of Amit in normal and vibration + ring condition is provided in table A5 and A6.

3) Name: Amit  
Age: 21 yrs.  
Sex: Male

The pulse rate in normal and vibration + ring condition is 64.6 and 63.33 respectively.

The heart rate analysis of Blal in normal and vibration + ring condition is provided in table A7 and A8.

4) Name: Blal  
Age: 22 yrs.  
Sex: Male

The pulse rate in normal and vibration + ring condition is 76.29 and 82 respectively.

The heart rate analysis of Sachin in normal and vibration + ring condition is provided in table A9 and A10.

5) Name: Sachin  
Age: 33 yrs.

Sex: Male

The pulse rate in normal and vibration + ring condition is 72.8 and 66.37 respectively.

**5.1. Indian students**

The normal mode recordings of Indian students are tabulated in table 1.

The names of the students are given in the first column. Next the measured beat per minute value (bpm) of the students is displayed. The averages of all the bpm values are then calculated. Next for each student the difference between bpm and bpm average is found. The values are squared and final output is taken.

Table 1. Normal mode – Indian students

Name	bpm	bpm avg	bpm-bpm avg (x)	x <sup>2</sup>	δ
Avenash	64.85	69.26	-4.41	19.44	2.20
Sachen	67.78		-1.48	2.19	0.73
Amit	64.60		-4.66	21.71	2.32
Blal	76.29		7.03	49.42	3.51
Sachin	72.8		3.54	12.53	1.76

The vibration + ring mode recordings of Indian students are shown in table 2.

Table 2. Vibration + ring mode

Name	bpm	bpm avg	bpm-bpm avg (x)	x <sup>2</sup>	δ
Avenash	70	71.13	-1.13	1.27	0.56
Sachen	74		2.87	8.23	1.43
Amit	63.3		-7.83	61.30	3.91
Blal	82		10.87	118.15	5.43
sachin	66.3		-4.83	23.32	2.41

## 6. CONCLUSION AND FUTURE ENHANCEMENT

From the above results, it is understood that heart rate varies between the readings of normal and vibration + ring modes. Overdose in penetration of electromagnetic waves from cellular phones into the human body can be reduced by avoiding frequent use of such devices. Filtering techniques can be introduced so that radioactive waves can be prevented from entering the human body. Devices with lower SAR (specific absorption rate) are advisable.

Some of the precautions to reduce the levels of radiation absorbed from using mobile phones are stated below. The phone should be kept 20cm away from the head and it reduces the radiation doses by about 98%. Use of hands free headsets dramatically reduces radiation emissions into the brain. Frequent use of phones and using phones for longer duration continuously must be avoided. There are a few devices that can be fit to the phone to reduce the radiation emission or allow the body to neutralise the effects. Such devices can be used, so that the radioactive waves entering the body get minimised.

### REFERENCES

- [1] Soo Beom Choi, Min Kyung Kwon, Jai Won Chung, Jee Soo Park, KilSoo Chung and Deok Won Kim, Effects of Short-Term Radiation Emitted by WCDMA Mobile Phones on Teenagers and Adults, BMC Public Health, Vol. 14, No. 438, 2014, pp. 1-9, <http://dx.doi.org/10.1186/1471-2458-14-438>.
- [2] Mustafa Naziroglu, Murat Yuksel, Seyit Ali Kose and Mehmet Okan Ozkaya, Recent Reports of Wi-Fi and Mobile Phone-Induced Radiation on Oxidative Stress and Reproductive Signaling Pathways in Females and Males, Journal of Membrane Biology, Vol. 246, No. 12, 2013, pp. 869-875 <http://dx.doi.org/10.1007/s00232-013-9597-9>
- [3] Jai Dev Singh and Ram Awtar Yadav, Health Complications Caused by Excessive Use of Smartphones, General Journal of Multidisciplinary Studies, Vol. 4, No. 2, 2015, pp. 115-123.
- [4] Eva van Rooij and Eric N.Olson, MicroRNAs: Powerful New Regulators of Heart Disease and Provocative Therapeutic Targets, The Journal of Clinical Investigation, Vol. 117, No.9, 2007, pp. 2369-2376 <http://dx.doi.org/10.1172/JCI33099>.
- [5] Frank J.Giordano, Oxygen, Oxidative Stress, Hypoxia, and Heart Failure, The Journal of Clinical Investigation, Vol. 115, No. 3, 2005, pp. 500-508, <http://dx.doi.org/10.1172/JCI24408>.
- [6] Armin Klapsa, Ivo Ponocnyb, Robert Winkerc, Michael Kundid, Felicitas Auersperge and Alfred Barthe, Mobile Phone Base Stations and Well-Being-A Meta-Analysis, Vol. 544, 2016, pp. 24-30, <http://dx.doi.org/10.1016/j.scitotenv.2015.11.009>.
- [7] Martin Roosli, Patrizia Frei, Evelyn Mohler and Kerstin Hug, Systematic Review on the Health Effects of Exposure to Radiofrequency Electromagnetic Fields from Mobile Phone Base Stations, Bulletin of the World Health Organisation, Vol. 88, No. 12, 2010, pp. 887-896, <http://dx.doi.org/10.2471/BLT.09.071852>.
- [8] Fumiharu Togo and Masaya Takahashi, Heart Rate Variability in Occupational Health-A Systematic Review, Industrial Health, Vol. 47, No. 6, 2009, pp. 589-602, <http://dx.doi.org/10.2486/indhealth.47.589>.
- [9] G.James Rubin, Lena Hillert, Rosa Nieto-Hernandez, Eric van Rongen and Gunnhild Oftedal, Do People with Idiopathic Environmental Intolerance Attributed to Electromagnetic Fields Display Physiological Effects When Exposed to Electromagnetic Fields? A Systematic Review of Provocation Studies, Bioelectromagnetics, Vol. 32, No. 8, 2011, pp. 593-609.
- [10] Anke Huss, Matthias Egger, Kerstin Hug, Karin Huwiler-Muntener and Martin Roosli, Source of Funding and Results of Studies of Health Effects of Mobile Phone Use: Systematic Review of Experimental Studies, Environmental Health Perspectives, Vol. 13, No. 3, 2008,

- <http://dx.doi.org/10.1590/S1413-81232008000300022>.
- [11] H.Seitza, D.Stinnera, Th.Eikmanna, C.Herra and M.Rooslib, Electromagnetic hypersensitivity (EHS) and Subjective Health Complaints Associated With Electromagnetic Fields of Mobile Phone Communication-A Literature Review Published Between 2000 and 2004, Science of the Total Environment, Vol. 349, No. 1–3, 2005, pp. 45–55.
- [12] Ryszard Andrzejak, Rafal Poreba, Malgorzata Poreba, Arkadiusz Derkacz, Robert Skalik, Pawel Gac, Boguslaw Beck, Aleksandra Steinmetz-Beck and Witold Pilecki, The Influence of the Call with a Mobile Phone on Heart Rate Variability Parameters in Healthy Volunteers, Industrial Health, Vol. 46, No. 4, 2008, pp. 409-417, <http://dx.doi.org/10.2486/indhealth.46.409>.
- [13] Karel A.Brookhuis, Gerbrand de Vries and Dick de Waard, The Effects of Mobile Telephoning on Driving Performance, Vol. 23, No. 4, 1991, pp. 309–316, [http://dx.doi.org/10.1016/0001-4575\(91\)90008-S](http://dx.doi.org/10.1016/0001-4575(91)90008-S).
- [14] Amanda Johanssona, Steven Nordinb, Marina Heidend and Monica Sandstroma, Symptoms, Personality Traits, and Stress in People with Mobile Phone-Related Symptoms and Electromagnetic Hypersensitivity, Journal of Psychosomatic Research, Vol. 68, No. 1, 2010, pp. 37–45, <http://dx.doi.org/10.1016/j.jpsychores.2009.06.009>
- [15] G.Oftedal, A.Straume, A.Johnsson and L.J.Stovner, Mobile Phone Headache: a Double Blind, Sham-Controlled Provocation Study, 2007, Vol. 27, No. 5, 2007, pp. 447–455, <http://dx.doi.org/10.1111/j.1468-2982.2007.01336.x>.
- [16] M.Thangamani, V.Ravindra Krishna Chandar, Adverse Drug Reactions using Data Mining Technique, Journal of Excellence in Computer Science and Engineering, Vol. 1, No. 1, 2015, pp. 11-14, <http://dx.doi.org/10.18831/djcse.in/2015011002> .

**APPENDIX A**

Table A1.Heart rate analysis of Avenash in normal condition

lead	P wave mV	PR interval sec	QT interval sec	ST interval sec	QRS complex sec	RR interval sec	Heart rate bpm
I	0.075	0.12	0.28	0.18	0.04	24	64.85
II	0.05	0.12	0.28	0.18	0.04	23.5	
III	0.05	0.08	0.28	0.18	0.04	21.9	

Table A2.Heart rate analysis of Avenash in vibration+ ring condition

lead	P wave mV	PR interval sec	QT interval sec	ST interval sec	QRS complex sec	RR interval sec	Heart rate bpm
I	0.05	0.08	0.3	0.18	0.04	22	70
II	0.075	0.08	0.3	0.18	0.04	21.7	
III	0.05	0.08	0.3	0.18	0.04	20.5	

Table A3.Heart rate analysis of Sachen in normal condition

lead	P wave mV	PR interval sec	QT interval sec	ST interval sec	QRS complex sec	RR interval sec	Heart rate bpm
I	0.125	0.12	0.26	0.18	0.04	22.9	67.78
II	0.15	0.12	0.26	0.2	0.04	21.5	
III	0.1	0.12	0.26	0.2	0.04	21	

Table A4.Heart rate analysis of Sachen in vibration+ ring condition

lead	P wave mV	PR interval sec	QT interval sec	ST interval sec	QRS complex sec	RR interval sec	Heart rate bpm
I	0.1	0.18	0.24	0.18	0.04	20.09	74
II	0.1	0.12	0.24	0.18	0.04	21	
III	0.1	0.12	0.24	0.18	0.04	21.7	

Table A5.Heart rate analysis of Amit in normal condition

lead	P wave mV	PR interval sec	QT interval sec	ST interval sec	QRS complex sec	RR interval sec	Heart rate bpm
I	0.075	0.12	0.3	0.2	0.04	24.5	64.6
II	0.075	0.12	0.28	0.2	0.04	22.02	
III	0.05	0.12	0.26	0.16	0.04	23.36	

Table A6.The heart rate analysis of Amit in vibration+ ring condition

lead	P wave mV	PR interval sec	QT interval sec	ST interval sec	QRS complex sec	RR interval sec	Heart rate bpm
I	0.075	0.12	0.3	0.24	0.04	23.8	63.33
II	0.075	0.12	0.28	0.24	0.04	23.8	
III	0.05	0.12	0.28	0.24	0.04	23.5	



Table A7.Heart rate analysis of Blal in normal condition

lead	P wave mV	PR interval sec	QT interval sec	ST interval sec	QRS complex sec	RR interval sec	Heart rate bpm
I	0.075	0.12	0.3	0.22	0.04	20	76.29
II	0.075	0.12	0.3	0.22	0.04	19.5	
III	0.075	0.12	0.3	0.22	0.04	19.5	

Table A8.Heart rate analysis of Blal in vibration+ ring condition

lead	P wave mV	PR interval sec	QT interval sec	ST interval sec	QRS complex sec	RR interval sec	Heart rate bpm
I	0.05	0.1	0.26	0.2	0.04	19	82
II	0.075	0.1	0.26	0.2	0.04	18	
III	0.075	0.1	0.26	0.2	0.04	17.5	

Table A9.Heart rate analysis of Sachin in normal condition

lead	P wave mV	PR interval sec	QT interval sec	ST interval sec	QRS complex sec	RR interval sec	Heart rate bpm
I	0.075	0.12	0.3	0.24	0.04	22	72.8
II	0.125	0.12	0.3	0.24	0.04	20	
III	0.075	0.12	0.3	0.24	0.04	20	

Table A10.Heart rate analysis of Sachin in vibration+ ring condition

lead	P wave mV	PR interval sec	QT interval sec	ST interval sec	QRS complex sec	RR interval sec	Heart rate bpm
I	0.1	0.08	0.3	0.24	0.04	23	66.37
II	0.1	0.08	0.28	0.24	0.04	22	
III	0.1	0.08	0.28	0.26	0.04	23	

APPENDIX B

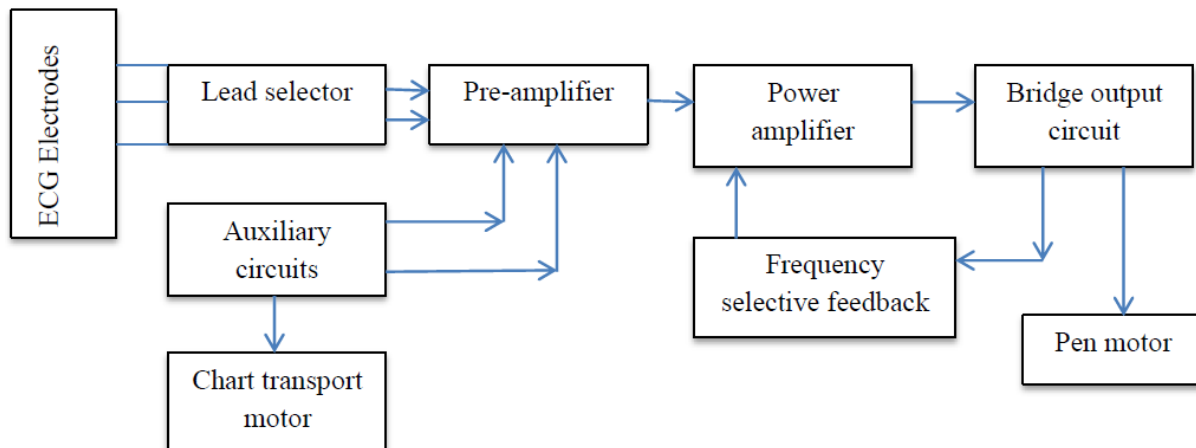


Figure B1. Block diagram of ECG