# HEALTH MONITORING SYSTEM (HMS) FOR RESCUERS

By

PANG WAN SIN

FINAL PROJECT REPORT

Submitted to the Department of Electrical & Electronic Engineering
in Partial Fulfillment of the Requirements
for the Degree
Bachelor of Engineering (Hons)
(Electrical & Electronic Engineering)

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# CERTIFICATION OF APPROVAL

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Approved:

______________________________

A.P. Dr. Irraivan Elamvazuthi
Project Supervisor

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May 2012

# CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

______________________________

PANG WAN SIN

# ABSTRACT

The main purpose of this project is to develop a system to remotely monitor real time measurement of physiological parameters of rescuers (firefighters, chemical rescuers etc.) who are exposed to hazard during rescue execution to fulfill the need for minimizing risks endangering rescuers' lives. It helps first-aid work as necessary support will be given once the person who monitor outside the field observes abnormal vital signs. The system consists of health monitoring device, computer and smartphone. The health monitoring device is a new generation of "smart" garments, integrating wearable sensors which will allow monitoring heart rate, breathing rate, skin temperature, posture and activity of the user. Sensors implemented ensure noninvasive measurement method, without interfering into human body. Computer and smartphone are used to communicate with the device's sensors that capture comprehensive physiological data from user. The acquired measurements are sent wirelessly via Bluetooth, and displayed on a computer or a smartphone. Real-time physiological measurements of rescuers can be observed. This paper will also discuss on the performance of the health monitoring device. The accuracy and reliability of health monitoring is tested. Further recommendations will be given to improve this system.

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# LIST OF ABBREVIATIONS

| | |
|---|---|
| API | Application Programming Interface |
| NIOSH | National Institute of Occupational Safety & Health |
| OSHA | Occupational Safety & Health Administration |
| PC | Personal Computer |

# CHAPTER 1
# INTRODUCTION

## 1.1 Project Background

Life only comes once. Nothing is more important than safety. When we face any danger or harm, rescuers are the people to save us from injuries. Then who are going to protect the rescuers when they face any danger? According to National Institute of Occupational Safety & Health (NIOSH) and Occupational Safety & Health Administration (OSHA), rescuers accounted for approximately 60% of confined space fatalities [1][2]. Lack proper health measure and monitoring tools is a reason causing that happen. The rescuers' lives need to be ensured when rescue operation. Thus, health monitoring system is introduced among the rescuers.

This project aims to develop a system to monitor rescuers' health vital signs. Health monitoring refers to checking on the status of computers to see if the wearers are still moving [3]. It is an informal, non-statutory method of surveying workforce for symptoms of several vital signs. Health monitoring device may comprise various types of miniature sensors [4]. These bio-sensors are capable of measuring vital physiological parameters. For examples, heart rate, breathing rate, skin temperature, activity level and posture. These parameters should be able to communicated via wireless and display on a central node which is small and easy to carry, for instances, smart phone.

Zephyr BioHarness 3 fulfils those main criterions and is chosen as the best health monitoring device to be used in this project [5]. By remotely monitoring those vital signs in a smart phone or computer, vital signs of the wearer can be known [4]. Related authorities can have instance access to real-time physiological measurements and they are able to provide prompt support and help in order to prevent further injuries when any abnormal signs are shown during emergency events.

## 1.2 Problem Statement

Many communication methods used by rescuers currently are ineffective. Team leader and the other rescuers of the same team use walkie-talkie to communicate with each other. The only way for the team leader to find out the rescuer's location and situation faced by them is by listening to their verbal report via walkie-talkie. What if the rescuers are fainted or injured during the rescue task operation? First aid support is very important to protect our lives. By using the current communication method, team leader has insufficient information of rescuers' health condition. Hence, necessary support and prompt help cannot be given when there is an emergency happens among the rescuers. This may increase the risk of getting injured and it might lead to death. Therefore, Health Monitoring System is introduced to the rescuers to overcome the problem of lacking proper measuring and monitoring tools among them.

### *1.2.1 Significance of the Project*

The findings from this research and project work are important to support the integration of the sensor with mobile devices and the performance of health monitoring device. It is used to transmit vital information among rescuers as well as to the one who remotely monitors their conditions so that when emergency happens while executing rescue tasks, they can have instance and reliable access to real-time physiological measurements and updated information. Thus, they are able to understand the situation to help and support each other to prevent further injuries.

## 1.3 Objectives

- To develop a system to monitor rescuers' health vital signs in real time
- To determine the best health monitoring device to be used to monitor parameters (vital signs) of the rescuers
- To determine the integration of the PC and smartphone with the device for this system
- To verify the accuracy and reliability of the health monitoring device

## 1.4 Scope of Study

Scope of study will take into considerations of functions and cost of the product, types of integration and types of sensor. Different ways of the integration between sensor and the computer or smart phone for remote monitoring will be included. Knowledge of Bluetooth API and Bluetooth Android API are essential for programming a better user interface on computer and smartphone. The connection time between 10-meter Bluetooth module and health monitoring device, including smartphone and computer, with varying distances will be tested and recorded. One of the factors, distance which may affect the accuracy of data transmitted and received via Bluetooth are included in the scope of this project.

# CHAPTER 2
# LITERATURE REVIEW

## 2.1 Information of Existing Products

There are many products in the market with different functions, cost and transmitter range. The prioritize criterion we need to consider is measured signals (parameters), platform used and cost. Research is done in order to choose the best health monitoring device to measure and monitor parameters (vital signs) of the rescuers. The result is shown in Table 1 [5][6][7][8] .

Table 1 : Information of existing health monitoring products[5,6,7,8]

| No. | Product | Measured signals (parameters) | Technique used | Sensor used | Connection Range | Platform | Cost |
|---|---|---|---|---|---|---|---|
| 1 | Sport Tracker Bluetooth Heart Rate Monitor [7] | i) Heart rate | - | Heart rate sensor | 20m /66ft. | Android and Nokia Symbian smartphone | RM244 |
| 2 | Wahoo Blue HR Heart Rate Strap [8] | i) Heart rate<br>ii) Speed | - | Heart rate sensor and speed sensor | 3m /10ft | Iphone 4S only | RM245 |
| 3 | Fitbit Ultra Wireless Tracker [6] | i) Heart rate<br>ii) exact steps taken<br>iii) calories burned<br>iv) distance travelled<br>v) Posture | - | MEMS 3-axis accelerometer<br>-measures motion to know calories burned, steps taken and distance traveled<br>MEMS altimeter<br>- measures vertical climb up stairs and hills | 9144m/ 30000ft | PC (Window or MAC) | RM381 |
| 4 | Zephyr BioHarness [5] | i) Heart rate<br>ii) Breathing rate<br>iii)Skin temperature<br>iv) Activity level<br>v) Posture | - | - ECG sensor<br>- Breathing sensor<br>- 3- axis Accelerometer<br>- Infrared sensor | 10m/ 30ft | Android smartphone and computers | RM1300 |

In terms of function, Sport Tracker Bluetooth Heart Rate Monitor can only measure heart rate [7] while Wahoo Blue HR Heart Rate Strap is able to measure heart rate and speed [8]. These parameters are not sufficient to know the physiology vital signs of the rescuers. Fitbit Ultra Wireless Tracker is able to measure heart rate, exact steps taken, calories burned, distance travelled and posture [6]. But these functions are more suitable for those people who want to keep a healthy diet and maintain healthy lifestyles. Compared to those products mentioned above, Zephyr BioHarness 3 can measure vital signs which are heart rate, breathing rate, skin temperature, activity level and posture [5]. These parameters can indicate the physiology condition of the rescuers and able to help the rescuers if any abnormal sign is found during rescue tasks.

From Table 1 [5][6][7][8], we can see that the *techniques used* column is blank. This is because the products mentioned above are all commercial products. The company will not explain the techniques used to measure those parameters and they will take that information as confidential. Different company used different method to measure various parameters which may affect the range, accuracy, transmission speed and etc. Consumers will consider the factors and purchase the products which fulfil their needs. The technique used for each product is confidential and this will make the product more competitive and has its own strength and advantages. To complete this project, research on how to measure the parameters have been done and will be discussed in the following section.

Connection range is one of the important factors for health monitoring system. BioHarness 3 has a 10-meter Bluetooth connection range [9][10]. This range is acceptable since this is a preliminary test for this project. After this project succeeds, we can figure out the method to make the Bluetooth connection range wider. With 10-meter range, a person who remotely monitors outside the field is able to receive the vital signs signal of the rescuers during rescue tasks. If any abnormal signs of the parameters are found, they are able to support and help the rescuers.

Overall, The Zephyr BioHarness is user-friendly. It is suitable to be used in popular platforms such as Android smart phones. Compared to the other products, the cost of Zephyr BioHarness is higher but Zephyr provides comprehensive functionality at a reasonable price. Zephyr product is able to remote monitoring of human performance and condition in the real-world. After considering and comparing cost and functions of every different product, Zephyr BioHarness is chosen to be used in this project [5].

## 2.2 Wireless Communication - Bluetooth

The most commonly employed wireless communication standards are IEEE 802.15.1 (Bluetooth) and IEEE 802.15.4 (Zigbee) [9][10][11][12].

Table 2 : Different types of wireless communication [9][10]

| Wireless Communication | Range (typical) | Data Rate (max) | Power Consumption | Frequency |
|---|---|---|---|---|
| Bluetooth | 10-100m | 1-3Mbps | 2.5-100mW | 2.4GHz |
| Zigbee | 10-75m | 20kbps/ 40kbps/ 250kbps | 30mW | 868MHz/ 915MHz/ 2.4GHz |

From the Table 2 [9][10], we know that the range of Bluetooth is slightly higher than Zigbee which is 10-100m and the max data rate can be received by Bluetooth is higher than Zigbee, which is 1-3 Mbps. Because of this reason, Bluetooth is chosen as the wireless communication to be used in this project.

Bluetooth is a proprietary wireless technology standard which allows wireless connections among electronic devices, for examples, printers, personal computers, notebooks, headsets, handphones, Global Positioning System (GPS) receivers, digital cameras, etc. By using short wavelength radio transmissions from 2400-2480 MHz frequency in the Industrial Scientific and Medical (ISM) band, allowing devices operating in the bandwidth to communicate among each other [6]. When different Bluetooth devices are connected together, a small network, called PAN (Personal Area Network), is created, and can be used to exchange data and information with high levels of security with a regular company LAN (Local Area Network).

Bluetooth is a packet-based protocol with a master-slave structure. One master can communicate with up to 7 slaves in a piconet (because a three-bit MAC address is used); all devices share the master’s clock. Piconet range will vary according to the class of the Bluetooth and the data transfer varies between 200 and 2100 kbit/s at the application. Every piconet has a different master. Each master has its own unique Bluetooth device name, address and clock. Thus, every piconet has its own unique frequency-hopping sequence to avoid cross transmissions between the devices by constantly changing channels and know which channel to be on can connected to [12].

Bluetooth is characterized by a low power (from 1 to 100mW) and a communication speed of around 1 Mbps. By considering of the power, Bluetooth devices can be categorized into 3 classes [9][10] as shown in Table 3.

Table 3 : Different class of Bluetooth [9][10]

| Class | Maximum permitted power | | Range |
|---|---|---|---|
| | (mW) | (dBm) | (m) |
| Class 1 | 100 | 20 | ~ 100 |
| Class 2 | 2.5 | 4 | ~10 |
| Class 3 | 1 | 0 | ~5 |

Bluetooth used in this project is in Class 2 according to the output power and operating range stated in the RF characteristics. Bluetooth compliance for BioHarness 3 is version 2.0 + EDR. This version of Bluetooth Core Specification is backward compatible with the previous version 1.2 which has faster connection and discovery, adaptive frequency-hopping spread spectrum (AFH). Crowded frequencies in the hopping sequence are avoided and thus improve resistance to radio frequency interference. The main difference is the introduction of an Enhanced Data Rate (EDR) for faster data transfer. EDR uses a combination of Gaussian Frequency-Shift Keying (GFSK) and Phase Shift Keying (PSK) modulation with two variants, π/4-DQPSK and 8DPSK. EDR provides lower power consumption through a reduced duty cycle. EDR enables the devices to attain much higher data rates and improves performance.

## 2.3 Parameters

### *2.3.1 Heart Rate Detection*

Heart rate is determined by the number of heartbeats per unit time, usually expressed as beats per minute (BPM). Heart rate can be measured by finding the pulse of the body [13]. This pulse rate can be measured at chest where an artery's pulsation is transmitted to the surface by using the chest strap with fabric sensors. The receiver uses the transmitted radio signal when a heart beat is detected to determine the current heart rate. A microprocessor which is continuously monitoring the ECG can calculate the heart rate [14].

A. John Camm et al (1996) found that variation in heart rate can be accessed by time domain methods, which is the easiest way to be performed [15]. Heart rate at any point in time or the intervals between successive normal complexes can be determined by this method. Normal-to-normal (NN) intervals and instantaneous heart rate can be detected in a continuous electrocardiographic (ECG) record as this is the most precise method to determine pulse. Dizziness or feeling light-headed, shortness of breath, chest discomfort and fatigue may cause irregular heart rate [16].

### *2.3.2 Breathing Rate Detection*

Breathing rate is defined as the number of breaths, which is inhalation and exhalation of a living being takes per unit time, usually in a minute. Breathing rate can be calculated by counting the number of times a person's chest expands and contracts in one minute. Michael R. Neuman (2011) stated that breathing can be measured by the motion of the chest and abdomen, breathing sounds, or the electrical properties of thoracic tissues [17]. The expansion and contraction of the thoracic cavity generates a size differential as measured by the sensor. This size differential is detected by the sensor and transmitted to the devices. This can be done via an ISM protocol to the RF dongle or antenna. Inhalation is denoted by a downward trend in the breathing waveform. This is because thoracic expansion cause the distance between the sensors in the strap decreased (compressed). On the other hand, exhalation (sensor expansion) causes an upswing in the waveform. Sine wave is appeared during respiration at rest while a higher frequency is appear during respiration under activity. Breathing rate may be lowered and often relate to a reduced level of consciousness [18].

### *2.3.3 Skin Temperature Detection*

Skin Temperature can be detected by the medical grade optical temperature sensor. The sensor is worked by using infrared [19]. The circulation of blood through body tissues will change the temperature at the surface of the skin. When exertion, excitement and stress increased, the muscles are forced to contract. Blood circulation of the tissues is reduced and causes a reduction of skin temperature. In contrast, the musculature is also bound to relax during a state of relaxation, this cause skin temperature rises [20]. The temperature of the environment might affect the skin temperature. Thus, it is necessary to measure in consistent surroundings.

### *2.3.4 Activity and Posture Detection*

The product used to detect the activity and posture contextualises the information with the individual’s physical activity using a 3-axis accelerometers. The operating principle of accelerometers is based on a mechanical sensing element which consists of a proof mass (or seismic mass) attached to a mechanical suspension system with respect to a reference frame. According to Newton’s Second Law, proof mass will deflect due to acceleration or gravity [21]. Najafi, 2003 stated that the sensor is commonly placed on the sternum to measure the whole-body movement [13]. The 3-axis accelerometer is able to classify postural transitions, falling, walking and other movements in X, Y and Z-axis. Accelerometer should be fitted and attached in order to prevent relative motion between the sensors and the parts of the human body.

Table 4 : Summary of bio-signals and sensors [4]

| Type of Bio-signal | Type of Sensor | Description of Measured Data |
|---|---|---|
| Heart rate | Skin electrodes | Frequency of the cardiac cycle |
| Breathing rate | Piezoelectric/ Piezoresistive sensor | Number of movements indicative of inspiration and expiration per unit time |
| Skin Temperature | Skin patch | A measure of the body's ability to generate and get rid of heat |
| Activity level and Posture | 3-axis Accelerometer | Measurement of acceleration forces in the 3D space |

## 2.4 Zephyr BioHarness 3 Health Monitoring Device.

### *2.4.1 Features [5]*

Refer to Appendix A.

With all these features, it is suitable for remote rescuers monitoring.

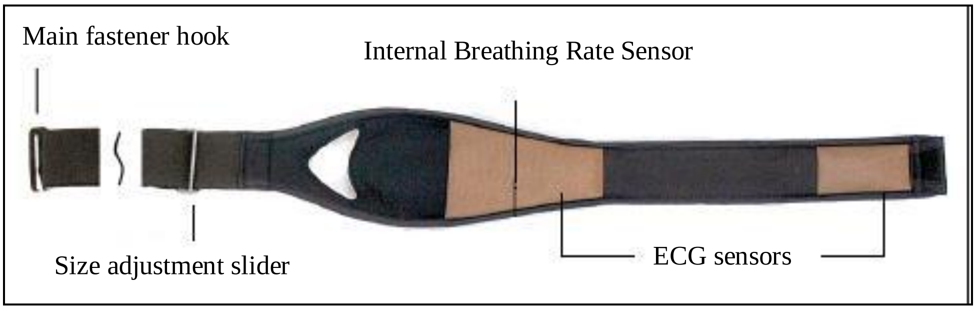


Figure 1 : Zephyr BioHarness 3 Side Strap (Back) [5]

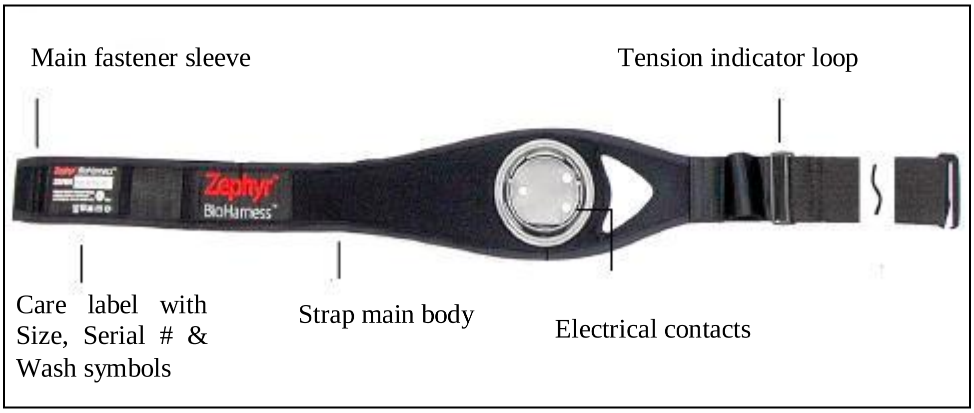


Figure 2 : Zephyr BioHarness 3 Side Strap (Front) [5]

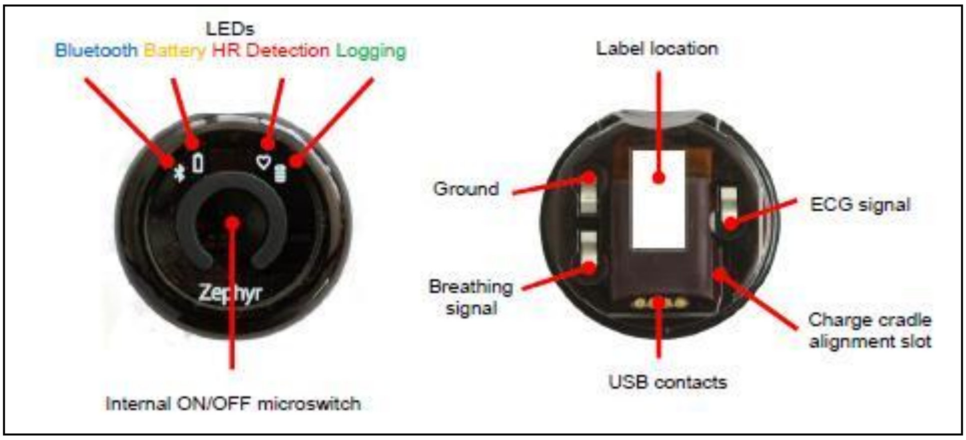


Figure 3 : Zephyr BioHarness 3 Device [5]

Figure 4 : Zephyr BioHarness 3 [5]

### 2.4.2 RF Characteristics

RF Characteristics of BioHarness 3 is described as below.

Table 5 : RF Characteristics of BioHarness 3 [5]

| | |
|---|---|
| Bluetooth Compliance | Version 2.0 + EDR |
| Supported Profile | Serial Port |
| Discoverability | Configurable |
| Operating Frequency | 2.4 to 2.835 GHz |
| Output Power | 2mW |
| Operating Range | 30ft / 10m typical radius indoors (line of sight) |
| Antenna Type | Internal |

### 2.4.3 Wireless Data Transmission and Data Logging

Zephyr BioHarness 3 is used as a device to transmit data received from the sensors. The BioHarness 3 is a compact electronics module. It is attached to a lightweight Smart Fabric strap which incorporates different physiological sensors. It can transmit physiology data by Bluetooth. The data will be recorded to internal memory and the cradle is used to obtain the data from internal memory. The features, specifications and output data will be discussed in the following section.

### 2.4.4 Specification

The specification of BioHarness 3 is described in Appendix B.

### 2.4.5 Environment

BioHarness BT should not be worn in explosive atmosphere, such as gas station and places near explosion area where radio detonation methods is used. This device has risk of fire or explosion when charged at high temperature, which is more than 45 ℃ and should not be disposed of in fire. The safe ranges of the device in different modes are stated as below [14].

Operating Temperature -30 ℃/+60 ℃

Storage Temperature -40 ℃ / +85 ℃ ; Charging Temperature 0 ℃ / +45 ℃

### *2.4.6 Wireless Data Receiver*

Data transmitted is received in the form of a number of messages, each of which can be enabled or disable. The data transmitted of BioHarness 3 can be referred in Appendix C.

# CHAPTER 3
# METHODOLOGY/PROJECT WORK

## 3.1 Research Methodology

Research is a method taken in order to gain information regarding the major scope of the project. The sources of the research include the handbook of BioHarness 3, e-journal, white papers and several reliable online sources.

**The steps of research:**

1. Research on the products with different functions and cost in the market which suitable to use in this project.

2. Compare advantages and disadvantages of the devices used to integrate with the sensor and determine the best device to use.

3. Research on the function, hardware and software of the product chosen.

4. Research on different types of integration of the sensor with the devices. For example, smart phone, iPhone, PDA and computer.

5. Identify parameters that can be measured by the health monitoring system.

6. Research on how the sensor measures parameters.

7. Research on the programming language used in the smart phone or computer to improve the health monitoring system.

## 3.2 Project Activities

In this project, we need to plan and execute the planned activities. The project activities for Final Year Project is stated in Figure 5.

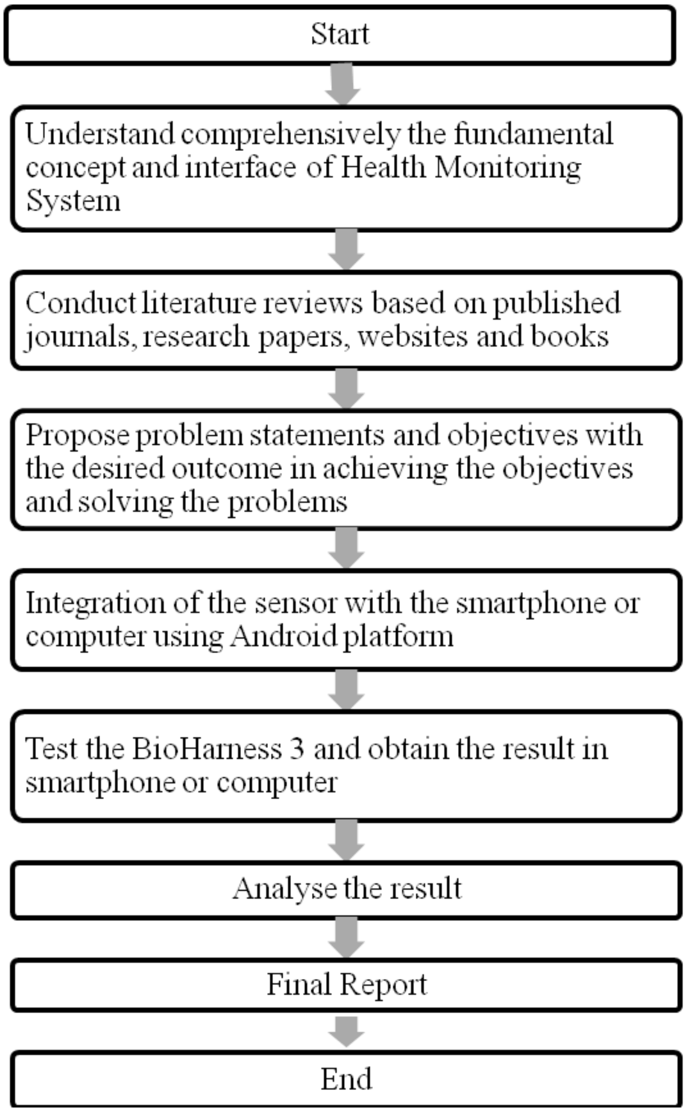


Figure 5 : Flow of Project Activities

## 3.3 Tools Required

To complete this project, the main hardware required are health monitoring device, which is Zephyr BioHarness 3, personal computer and smartphone. The main software required in this project are Eclipse programming platform for Java and Android application, Bluetooth Connection Wizard, Configuration Tool, and Microsoft Excel. Please refer to Appendix D.

# CHAPTER 4
# RESULT AND DISCUSSION

This chapter presents the result of the output response of the BioHarness 3 with respect to the response of heart rate and breathing rate. The result of the project is divided into three parts; whereby the first part is the result obtained when the subject is sitting (rest) and the second part is the result obtained when the subject is standing (rest). The last part is the result obtained when the subject is running on the spot. These 3 activities are repeated for 5 times and each time is 1 minutes. Average of the 5 experiments for each activity is calculated.

## 4.1 System Configuration

Rescuers will wear the health monitoring device at the proper position as shown in Figure 6 [4]. They need to make sure the device is fitted and attached to prevent relative motion in order to obtain accurate measurements. The HMS will be connected by using Bluetooth as shown in Figure 7 [4].

The smart phone used to receive the data transmitted from the health monitoring device should have powerful processing capabilities which is 624 MHz processor and able to support for standard JAVA APIs which include JAVA API for Bluetooth.

The health monitoring device can integrate with smart phone and personal computer by using Bluetooth.

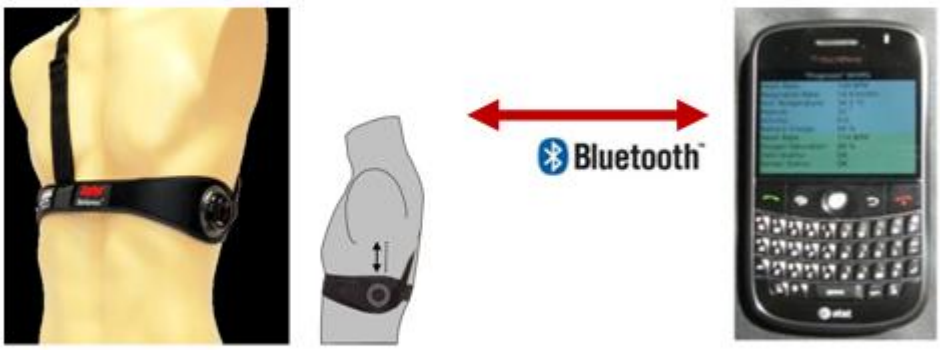


Figure 6 : Integration between health monitoring device and smart phone [4]

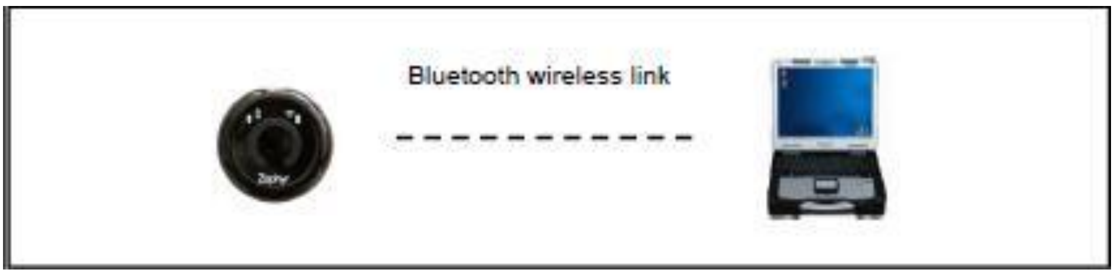


Figure 7 : Integration between health monitoring device and PC [4]

The rescuers wear health monitoring device which is able to measure the physiological signals (heart rate, breathing rate, skin temperature, activity level and posture). These parameters are sensed by biosensors. The biosensors amplify, filter and convert the data received from analogue to digital data and transmit the data to central node (smart phone) via wireless communication (Bluetooth).

### *4.1.1 The Overall System Flow*

During rescue task, rescuers will be given a wearable health monitoring device which consists of multi biosensors, in this project, Zephyr BioHarness 3 is used. The sensors measure the physiological signs of the rescuers. Data obtained is transmitted and received via wireless communication protocol which is Bluetooth. The data will be stored in management system. The overall system flow of HMS is shown in Figure 8 and detailed data management system is shown in Figure 9. Figure 10 shows the detailed concept of the project.

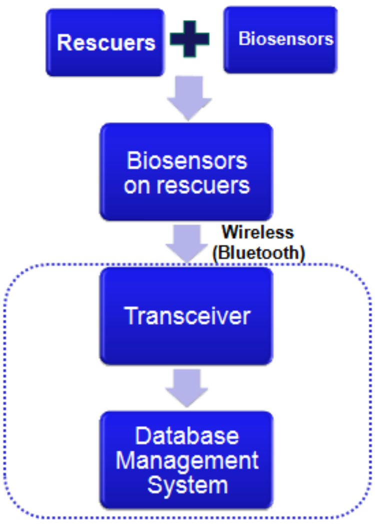


Figure 8 : HMS Configuration Block Diagram

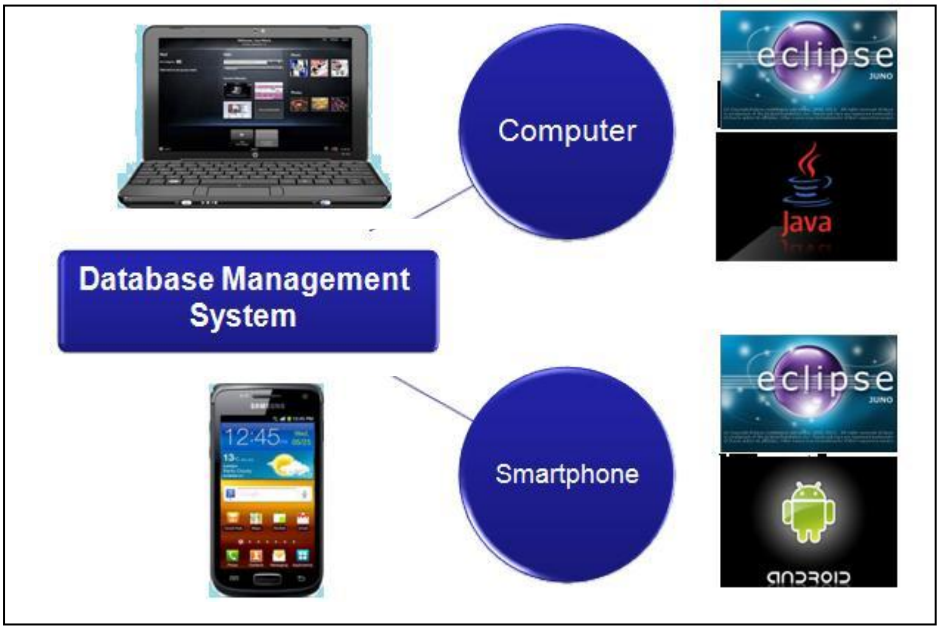


Figure 9 : Database Management System

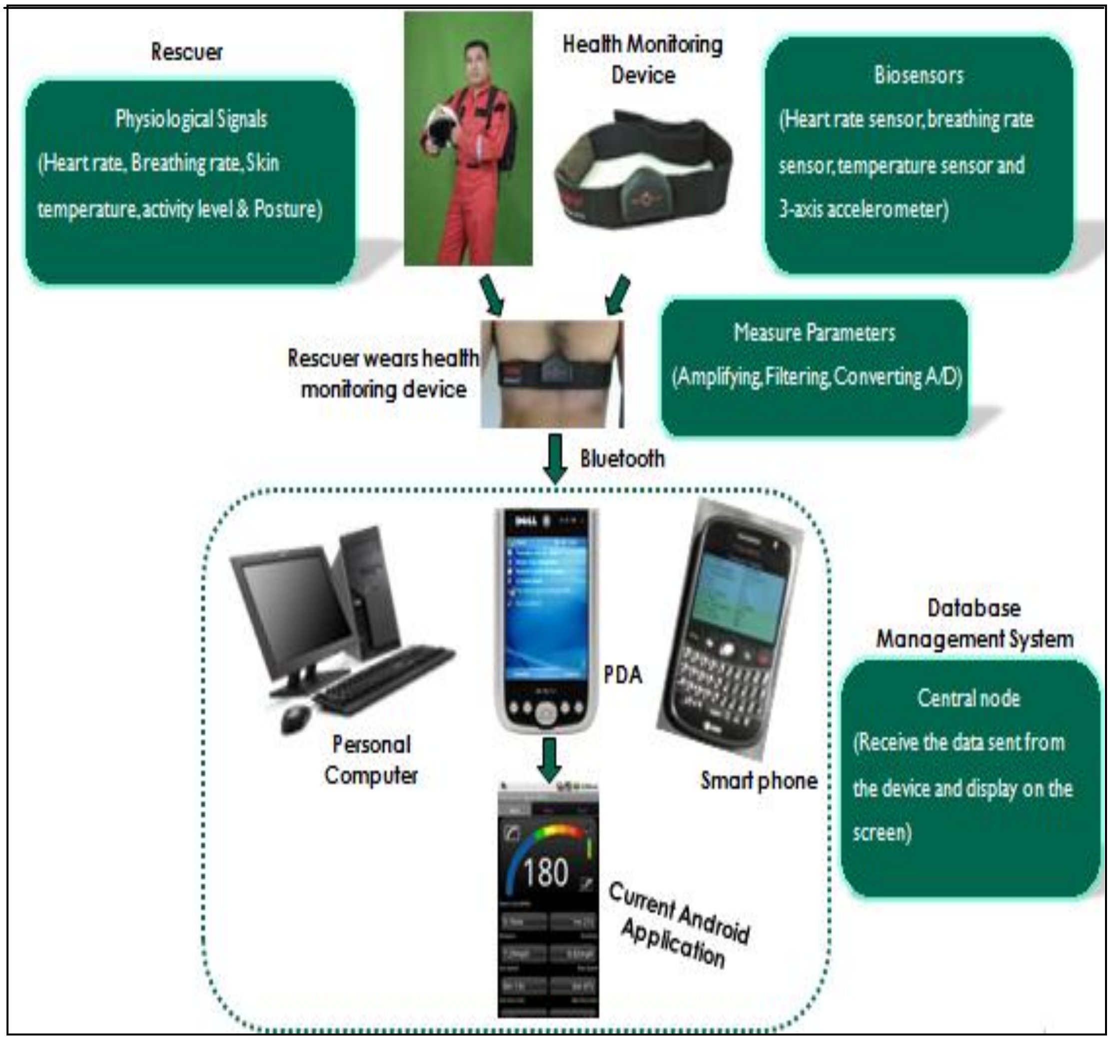


Figure 10 : System Configuration

The HMS will be used within the confined space due to its 10-meter connection range. By using Bluetooth wireless communication protocol, the health monitoring device wore by the team leader in a rescue team acts as "master" device. A master device can communicate with up to seven devices (slave) in a piconet [9][10]. The entire health monitoring device wore by team members in a rescue team are connected to team leader by using Bluetooth. The main leader who is outside the field will receive all the rescuers' physiological signs in a rescue team from team leaders by using another radio frequency (RF) wireless communication protocol which has a greater connection range [23]. This relationship can be explained by using Figure 11.

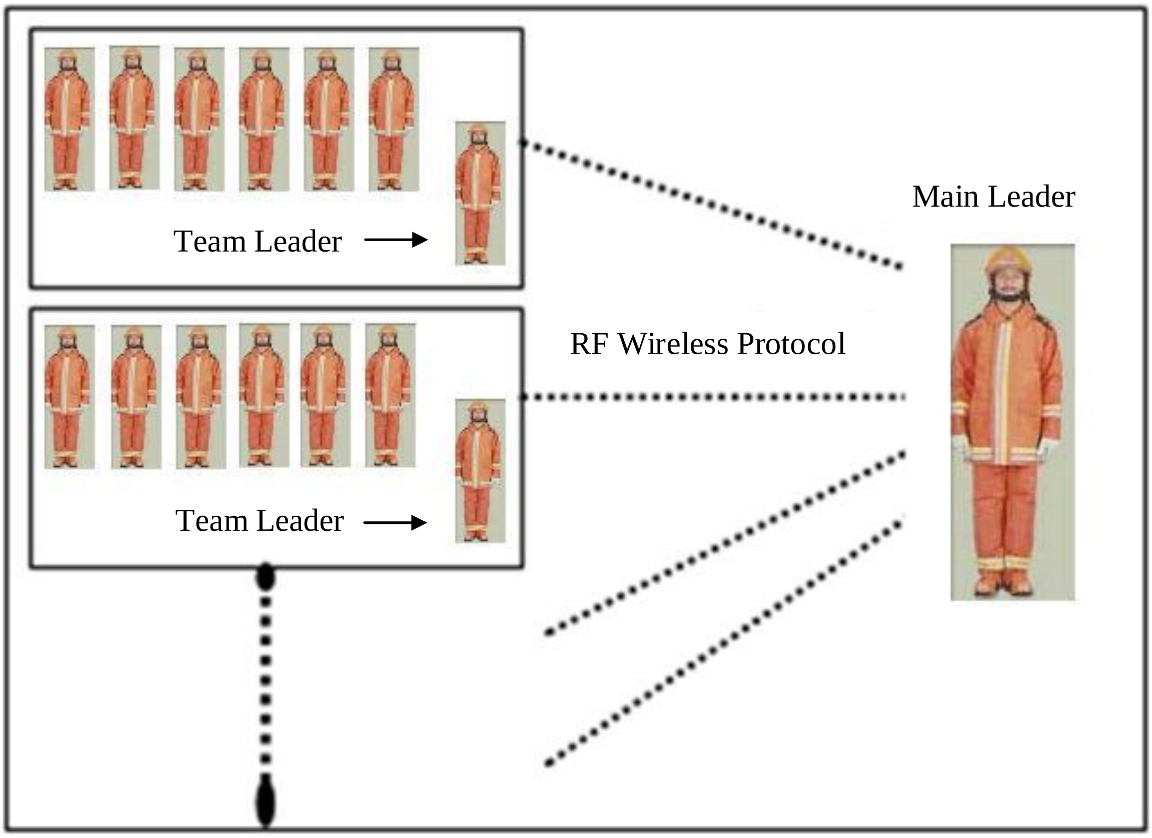


Figure 11 : Wireless Connection

### *4.1.2 Java Coding*

Before the Bluetooth BioHarness Test Application is used to measure the physiological vital signals, an introduction window is shown as Figure 12. The java coding is as below.

```
import java.awt.*;//For Color, container, and panel
import javax.swing.*;

public class MainClass implements Runnable{
//@Override
private JFrame frame = new JFrame();
	private JLayeredPane lpane = new JLayeredPane();
	private JPanel panelTop = new JPanel();
	private JPanel panelMid = new JPanel();
	private JPanel panelBott = new JPanel();

	public void run() {
		frame.setTitle("Universiti Teknologi PETRONAS");
		frame.setSize(500,350);
		frame.setDefaultCloseOperation(JFrame.EXIT_ON_CLOSE);
		frame.setLayout(new BorderLayout());
		frame.add(lpane,BorderLayout.CENTER);
		lpane.setBounds(0,0,500,350);
		panelTop.setBackground(Color.MAGENTA);
		panelTop.setBounds(0,0,500,350);
		panelTop.setOpaque(true);
		panelBott.setBackground(Color.ORANGE);
		panelBott.setBounds(0,40,500,310);
		panelBott.setOpaque(true);
		panelMid.setBackground(Color.ORANGE);
		panelMid.setBounds(0,273,500,40);
		lpane.add(panelTop,new Integer(0),0);
		lpane.add(panelBott,new Integer(1),0);
		lpane.add(panelMid,new Integer(2),0);
		frame.setVisible(true);
		panelTop.add(new JLabel("HEALTH MONITORING
SYSTEM",JLabel.CENTER));
		panelBott.add(new JLabel ("by PANG WAN SIN",JLabel.CENTER));
		panelBott.add(new JButton("Heart Rate"));
```

```
                    panelBott.add(new JButton("Breathing Rate"));
                    panelBott.add(new JButton("Skin Temperature"));
                    panelBott.add(new JButton("Posture"));
                    panelBott.add(new JButton("Activity"));
                    JButton start_button = new JButton("START");
                    panelMid.add(start_button);
                    GridLayout layout = new GridLayout(8,0);
                    panelBott.setLayout(layout);

start_button.addActionListener(new java.awt.event.ActionListener() {
                    public void actionPerformed(java.awt.event.ActionEvent e)
                    {
                              //Execute when button is pressed
                              try
                              {
          //                              JOptionPane.showMessageDialog(null, "hi");
                                        Process p = Runtime.getRuntime().exec("cmd /C
\"C:/BH3_SDK/Bluetooth Test Application/BioHarness Bluetooth Test Application
V2.application\"");
                                        System.exit(0);
                              }
                              catch (Exception ex){
                                        ex.printStackTrace();
                              }
                    }
                    }
          );
}
public static void main (String[] args) {
 MainClass se = new MainClass ();
 SwingUtilities.invokeLater(se); }
 }
```

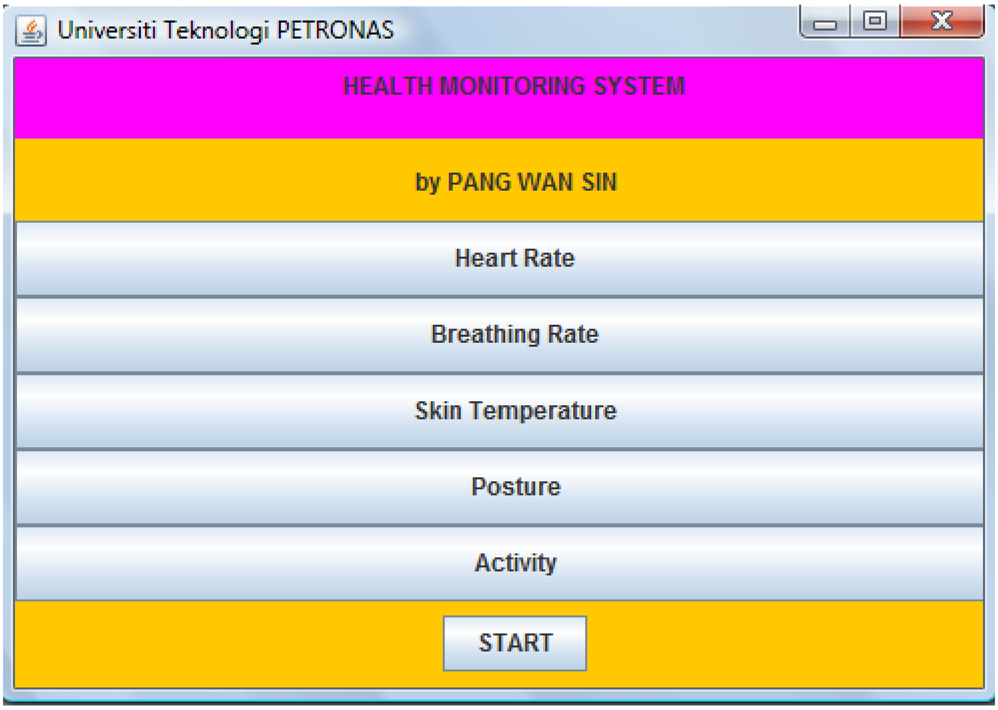


Figure 12 : Graphical User Interface for Personal Computer (cover)

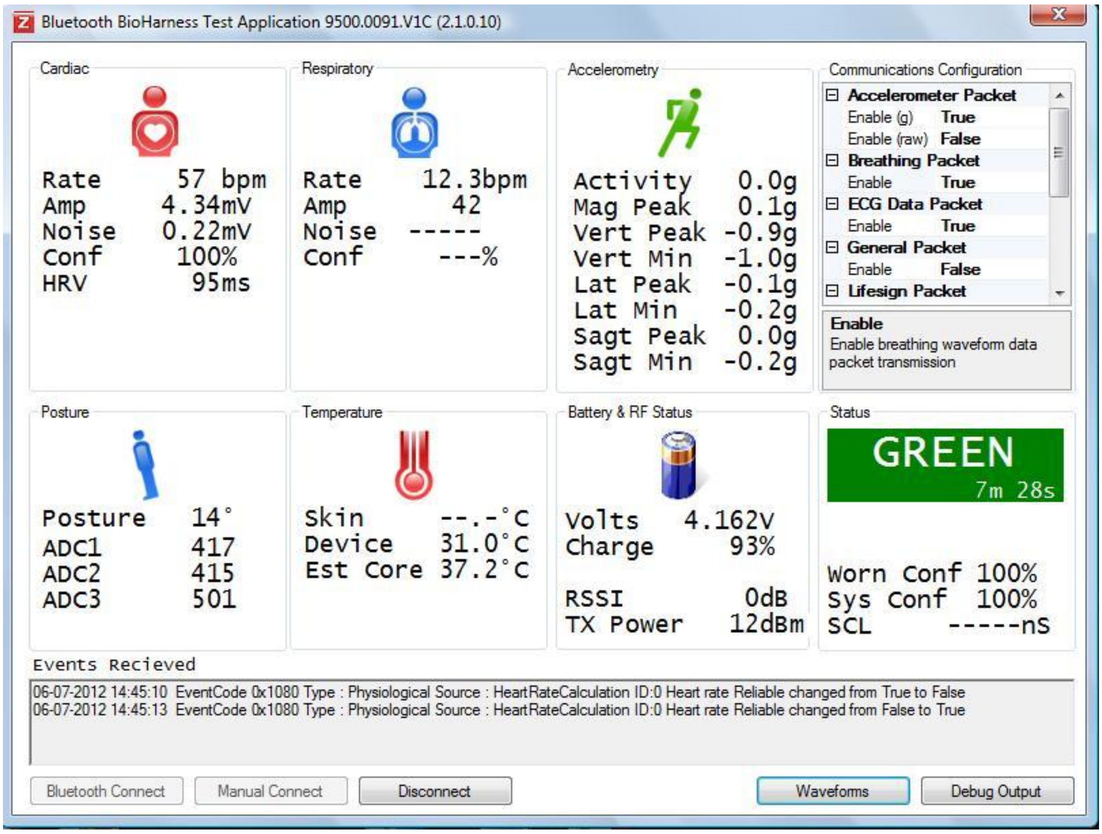


Figure 13 : Graphical User Interface for Personal Computer

Once the BioHarness 3 device is found and connected to the personal computer, the Bluetooth BioHarness device will record the physiological vital signs to the internal memory. The cradle is used to log the data from the internal memory and the data is in Excel format. The graphs are plotted as below to indicate the data obtained when the subject is doing different activity under the same environment and same ambient temperature.

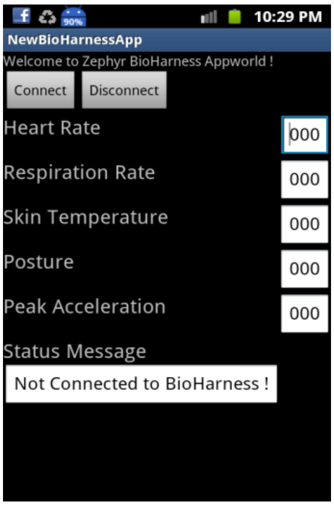


Figure 14 : User Interface for Smartphone

## 4.2 System Analysis

The experiments were carried out under the same environment and same ambient temperature. Connection time of health monitoring device to computer or smartphone and two parameters, which are heart rate and breathing rate will be tested.

### *4.2.1 Connection Time*

The connection time between 10-meter Bluetooth module and health monitoring device, including smartphone and personal computer, with varying distances is measured and recorded in Table 6. The connection time almost the same, with varying distances for free space.

Table 6 : The connection setup time

| Distance | Connection Time (sec) | |
|---|---|---|
| | Device to Computer | Device to Smartphone |
| < 1m | 4.5 | 2.5 |
| 1m - 3m | 4.1 | 3.0 |
| 3m - 6m | 4.3 | 2.9 |
| 6m - 9m | 4.4 | 3.5 |
| Average | 4.33 | 2.98 |

### *4.2.2 Rest Condition*

Two rest conditions, which are sitting and standing will be tested.

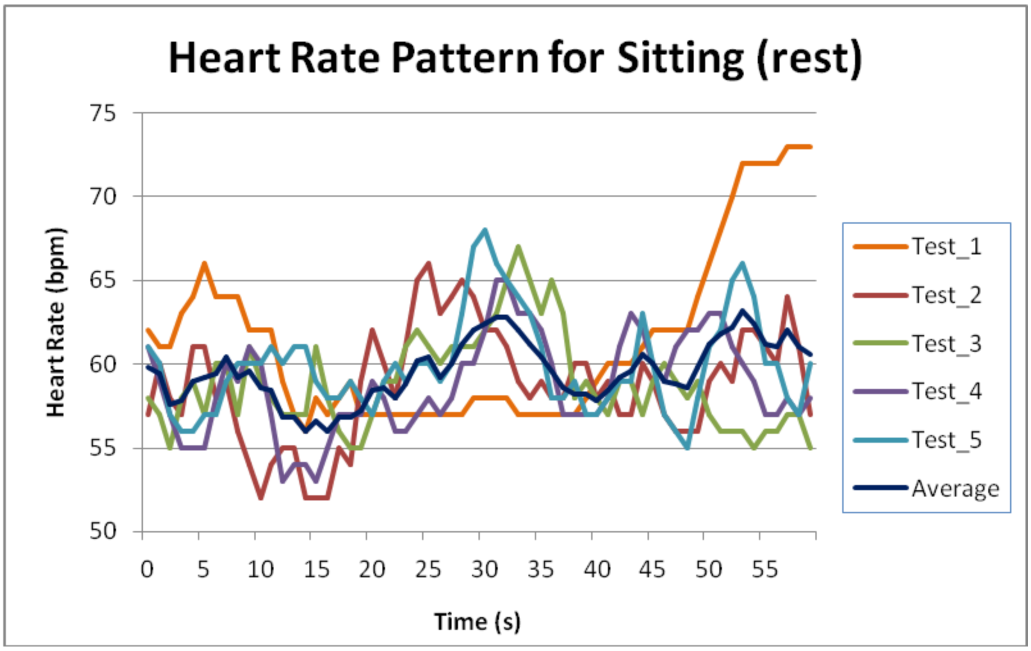


Figure 15 : Heart Rate Pattern for Sitting

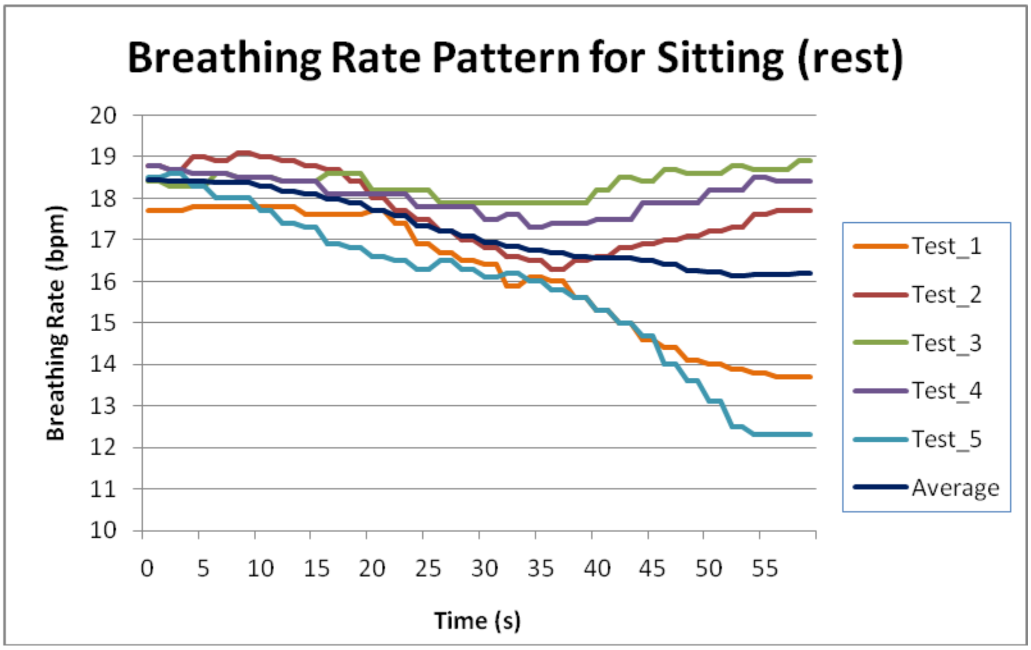


Figure 16 : Breathing Rate Pattern for Sitting

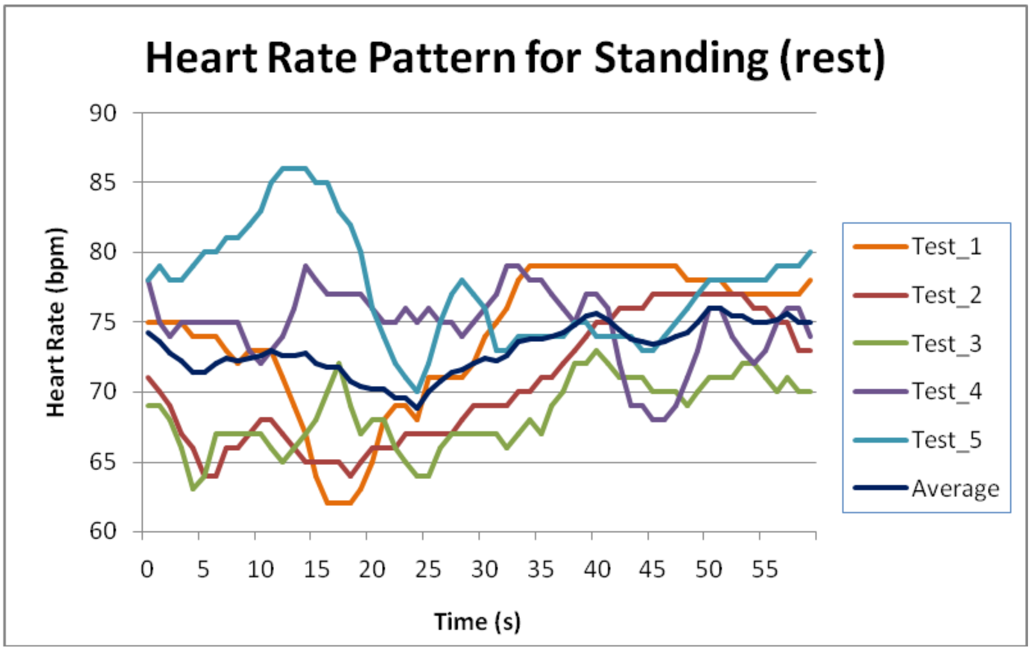


Figure 17 : Heart Rate Pattern for Standing

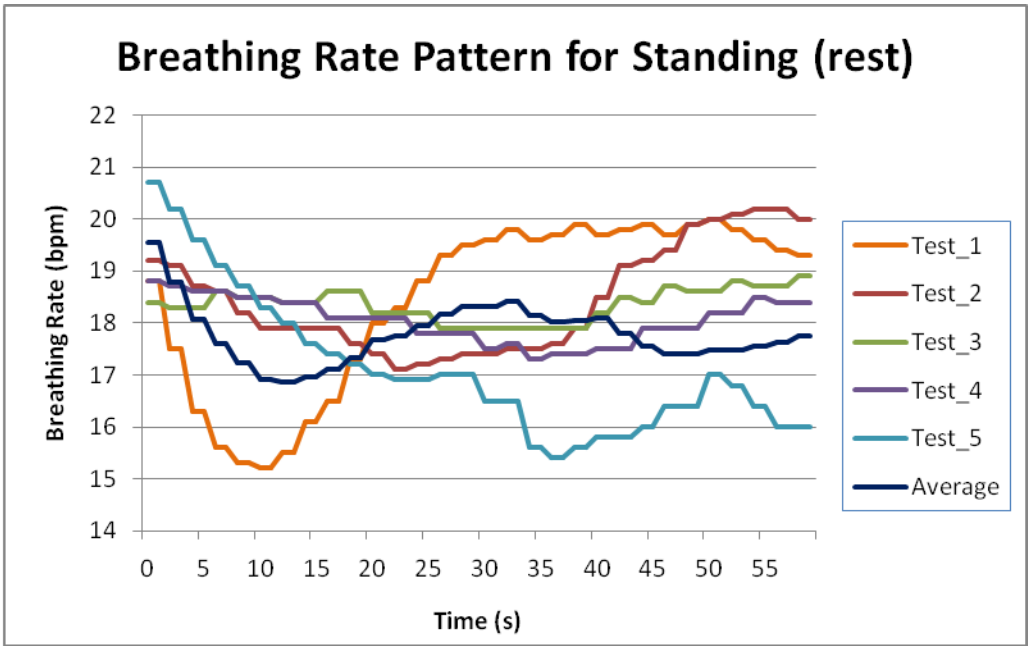


Figure 18 : Breathing Rate Pattern for Standing

A resting heart rate anywhere in the range of 60-90 beats per minute is considered in the normal range. Many athletes have pulse rates in the 40-60 range, depending on how fit they are. In general, a lower pulse rate is good. From Figure 15 and Figure 17, we can see that the heart rate is in the range of 50-90 beats per minute. It is normal and can see that the subject is fit. Sitting is the most preferred position to take the pulse. Average respiratory rate in a healthy adult at rest is usually given as 12-20 breaths per minute. From Figure 16 and Figure 18, we can see that the breathing rate is in the range of 15-21 breaths per minute, slightly higher than the normal range.

The heart rate pattern and breathing rate patter shown in Figure 15, Figure 16, Figure 17 and Figure 18 have small standard deviation which is tolerable and acceptable. The accuracy of the health monitoring device is verified.

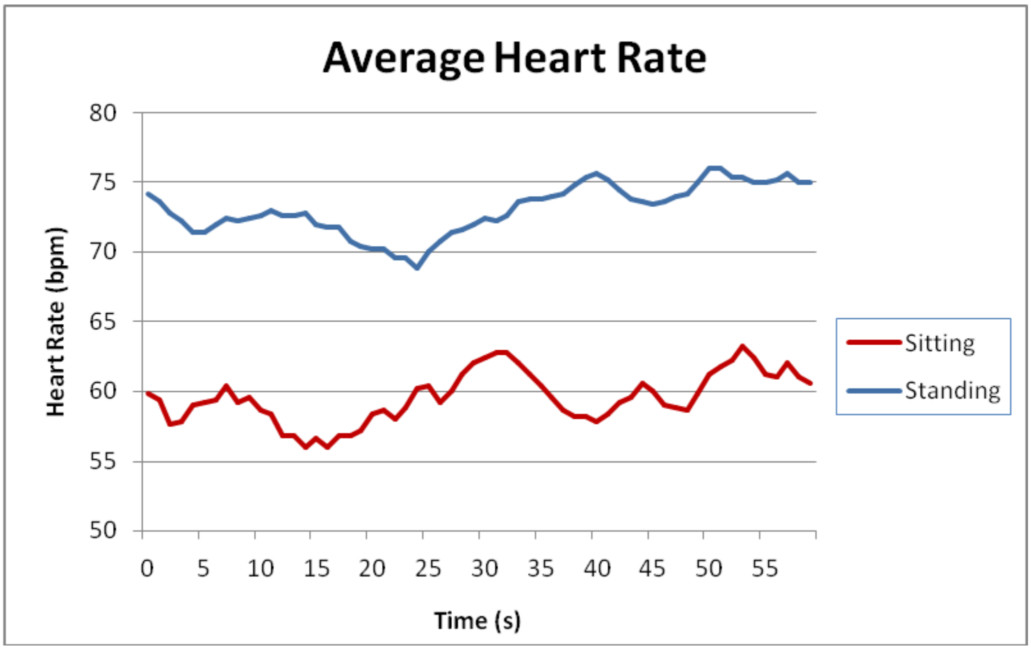


Figure 19 : Comparison of Heart Rate Pattern for Rest Condition

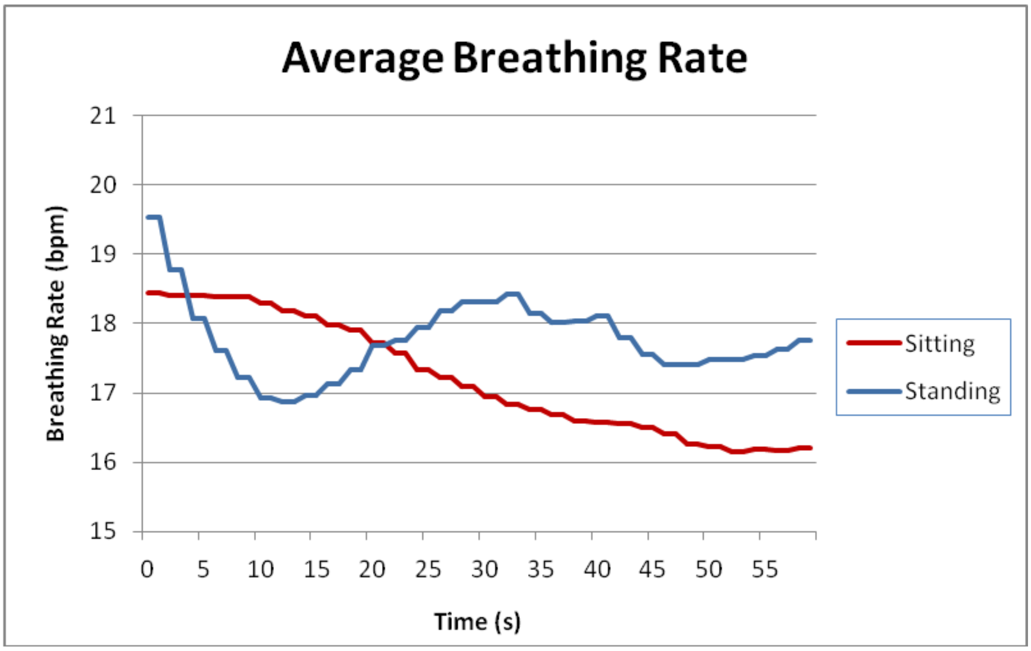


Figure 20 : Comparison of Breathing Rate Pattern for Rest Condition.

From Figure 19, we can notice that the heart rate pattern for standing is a bit higher than the heart rate pattern for sitting, which is 68-78 beats per minutes. It is still within the normal range. The reason caused the higher heart rate might be the body positioning. Taking pulse in different body positions will give different results. Heart rate for sitting will be lower than the heart rate for standing. It is due to the less gravitational pull on the circulatory system when the body is in a horizontal position therefore making the heart's job easier. The heart needs more pressure to circulate blood vertically throughout the body when standing. Therefore, sitting is the most preferred position to take the pulse

We can notice from Figure 20, the breathing rate for standing is a bit higher than sitting, which is 16-20 breaths per minutes. It is still within the normal range. When the subject is standing up, he/she is using more muscles because muscles are required to hold the subject in position. The muscles use energy which requires oxygen, therefore breathing rate will increase slightly to help to achieve this movement.

### *4.2.3 Running on the Spot for Vary Distances*

The performance of the health monitoring device is further tested, with varying distances. The computer is placed 0.5meter, 5 meter and 10meter away from health monitoring device. The subject will run on the spot. In this project, heart rate and breathing rate will be recorded only.

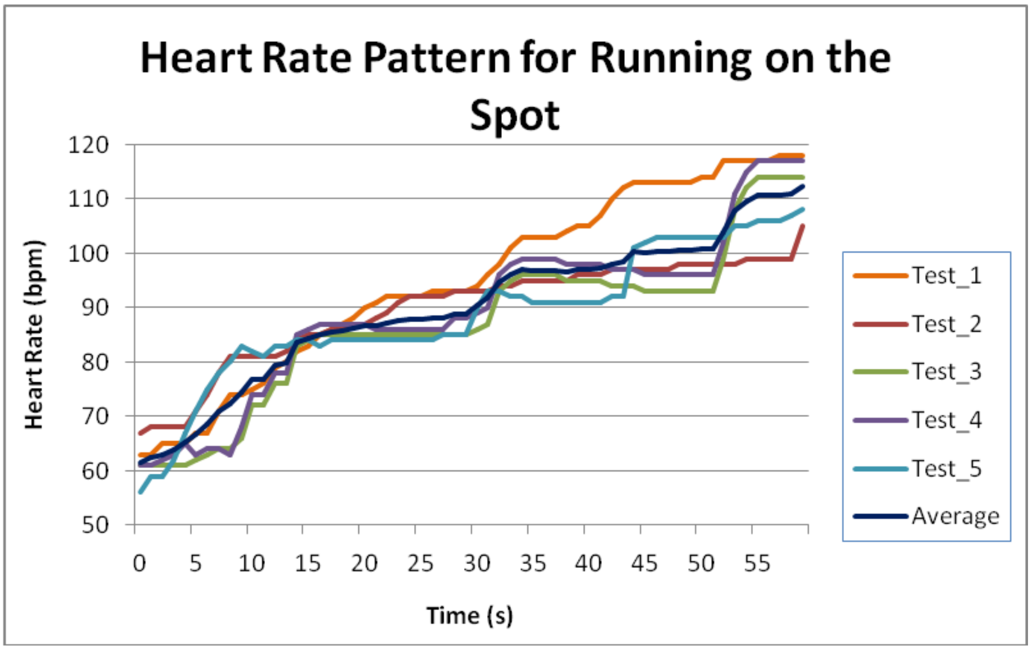


Figure 21 : Heart Rate Pattern for Running on the Spot (0.5meter)

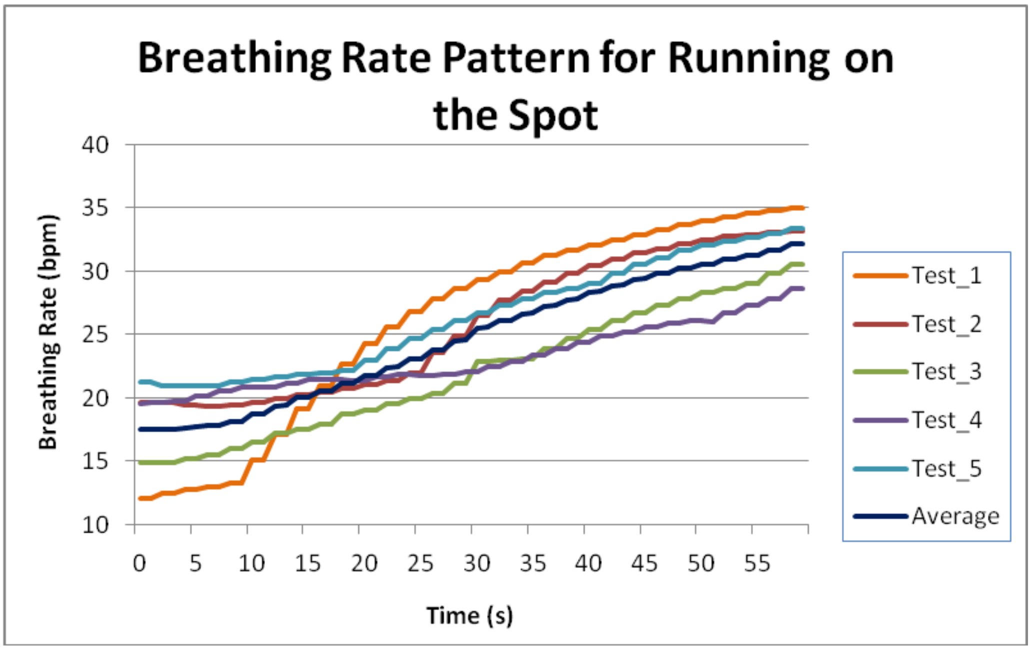


Figure 22 : Breathing Rate Pattern for Running on the Spot (0.5meter)

As shown in Figure 21 and Figure 22, it was found that the trend of heart rate and breathing rate is similar for the five repetitive experiments. The results of five tests overlap with each other. The heart rate and breathing rate slowly increase as time goes on. From the graph, we can identify that the personal computer can receive the excellent signal from health monitoring device.

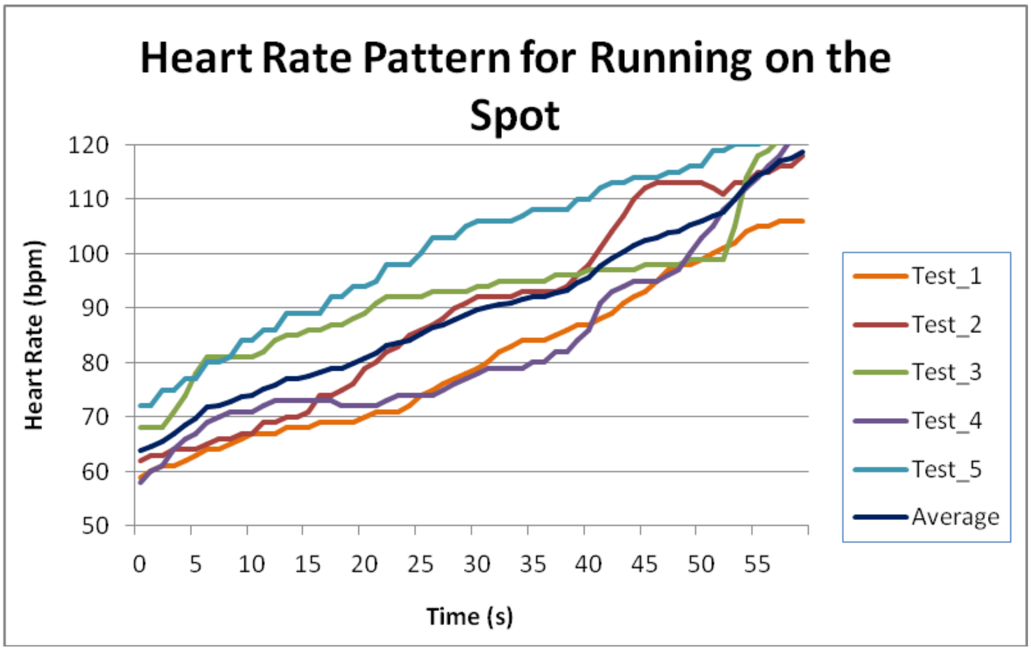


Figure 23 : Heart Rate Pattern for Running on the Spot (5meter)

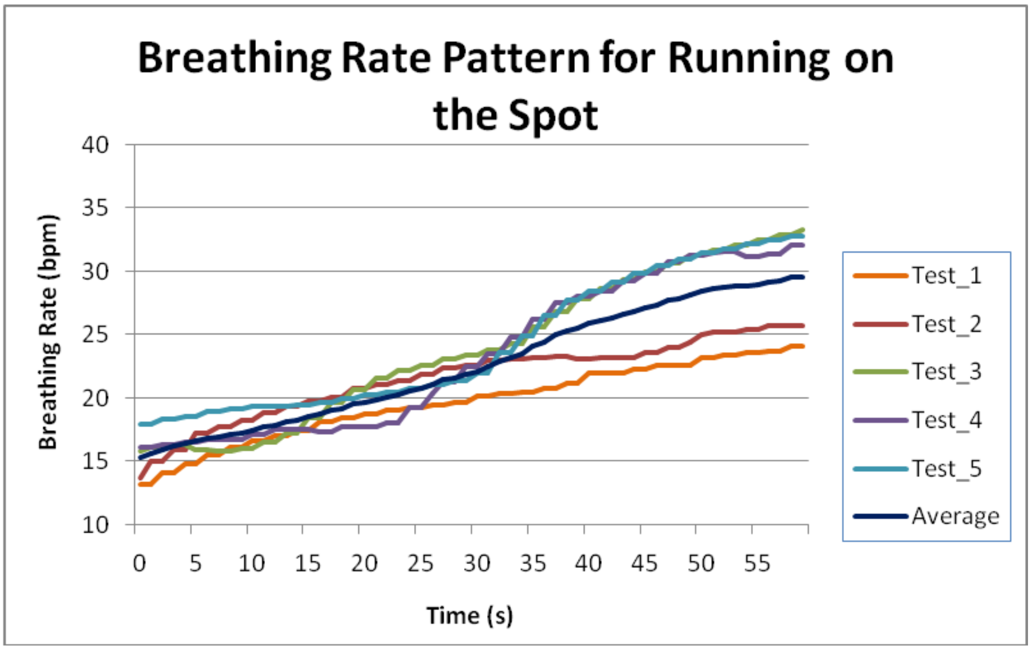


Figure 24 : Breathing Rate Pattern for Running on the Spot (5meter)

As compared to the result obtained for 0.5meter experiment, heart rate pattern for 5 meter for five repetitive experiments is not so compact. This is shown in Figure 23. The sensitivity of data is slightly reduced, but it does not affect the accuracy of the data obtained. Trend of breathing rate for five repetitive experiments is similar, as shown in Figure 24.

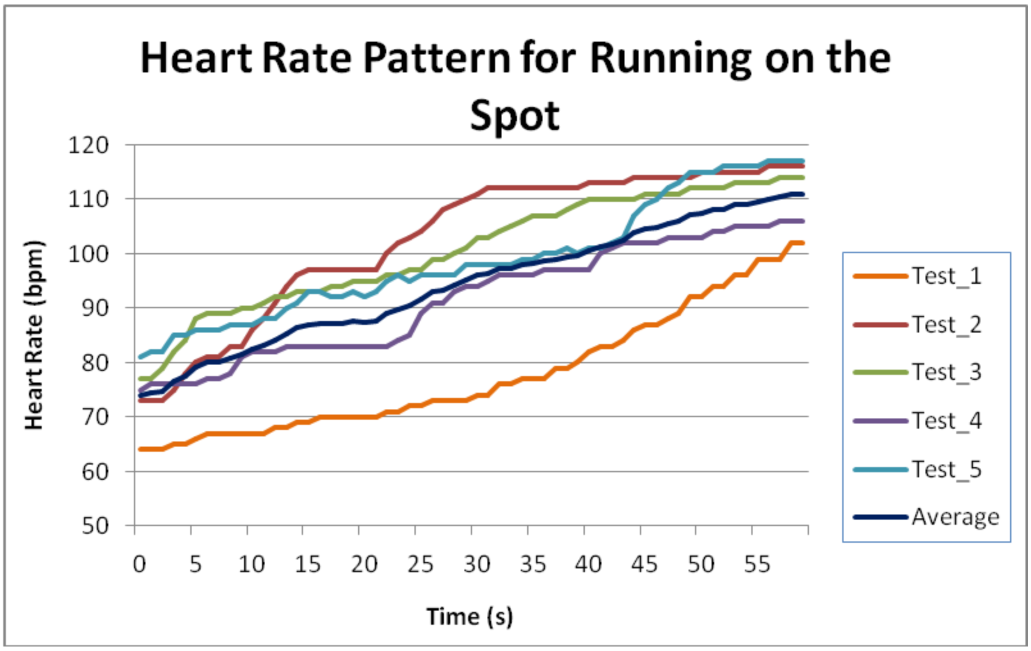


Figure 25 : Heart Rate Pattern for Running on the Spot (10meter)

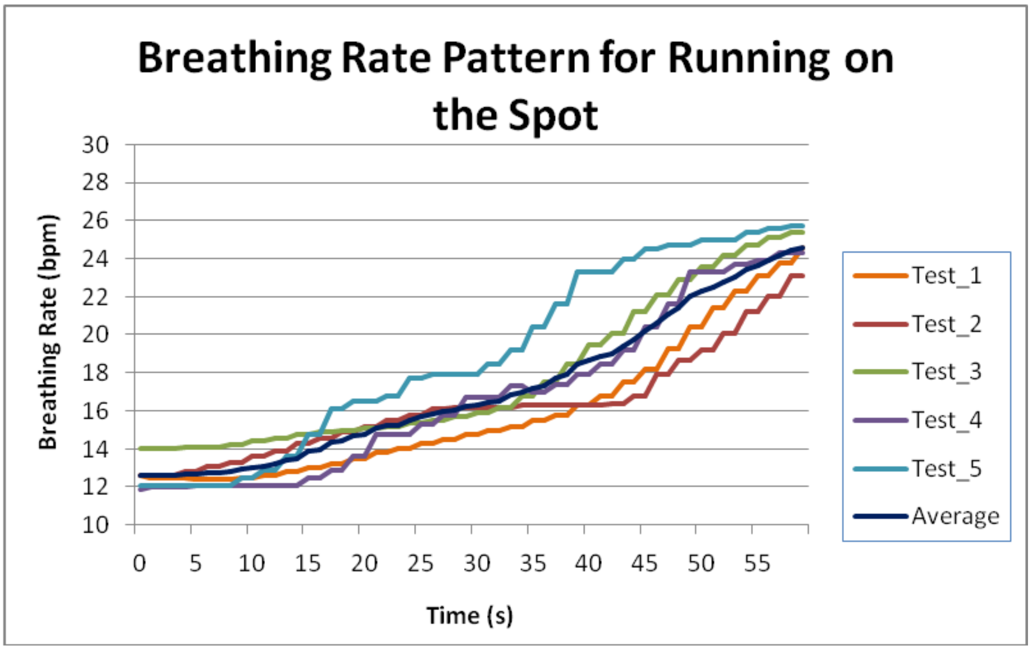


Figure 26 : Breathing Rate Pattern for Running on the Spot (10meter)

From Figure 25, it can be seen that the Test_1 curve is obviously lower than the others. This is due to the resting heart rate at the beginning. Our body still not yet warm up from the rest condition. Trend of heart rate and breathing rate for five repetitive experiments are similar as shown in Figure 26.

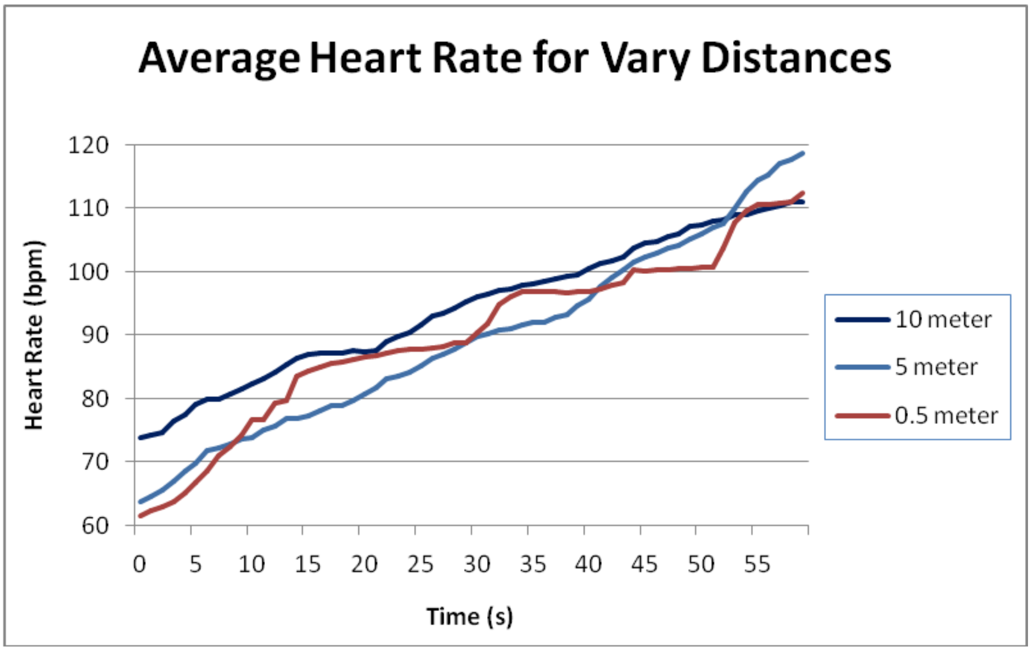


Figure 27 : Comparison of Heart Rate for 0.5meter, 5meter and 10meter

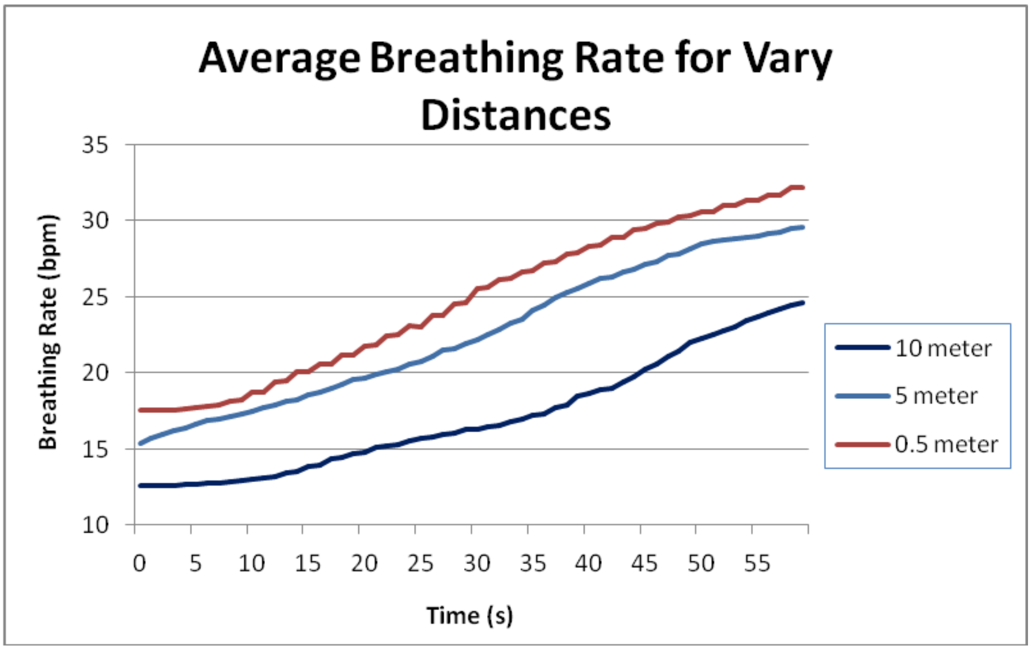


Figure 28 : Comparison of Breathing Rate for 0.5meter, 5meter and 10meter

For Figure 21, Figure 23 and Figure 25, we can conclude that the heart rate increases during the exercise, for example jogging. The longer the exercise the more oxygen is needed because body needs to supply oxygen to the working muscles to produce energy. Thus, breathing rate will increase, as shown in Figure 22, Figure 24 and Figure 26.

The heart rate range for three different distances is in the range of 60-120bpm while the breathing rate are in the range of 10-35bpm. From Figure 27 and Figure 28, it can be noticed that the graph for 10meter experiments have gentle slope compared to the steep slope of the graph of 0.5meter experiments. Transmission rate is affected by distance. The standard deviation is low when the health monitoring device is close to the computer, as the signal strength remains consistently high. This proves that the distance of two Bluetooth devices can affect the data transfer rate. Signal will degrade significantly at over 12meter [22].

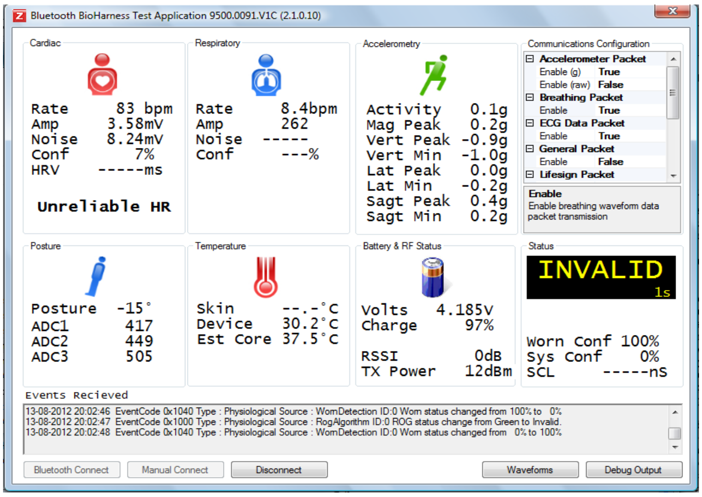


Figure 29 : Test Application for Personal Computer

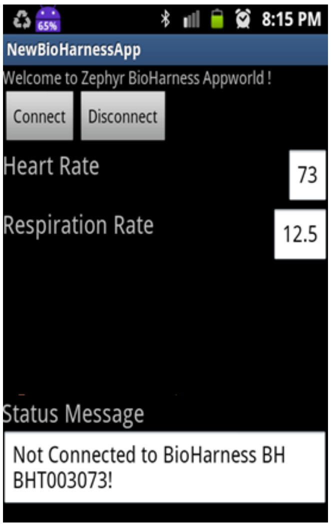


Figure 30 : Android Application for Smartphone

Once the distance between health monitoring device and receivers is greater than 12meter, "Status" will notify the observer. For computer, "Unreliable HR" in Cardiac and "INVALID" in Status will be shown. This is shown in Figure 29. For smartphone, "Not Connected to BioHarness BH" will be shown as Figure 30 to indicate the loss of connection between the servers. However, as long as the rescuers who wear the health monitoring stay within the range, the signal received is accurate and reliable.

# CHAPTER 5
# CONCLUSION & RECOMMENDATION

In conclusion, this project presents the functions of HMS aimed at monitoring health sate of rescuers in real time. The HMS for rescuers is an easy-to-use and reliable system that helps prevent further injuries by giving support immediately once abnormalities of physiological signs is detected in hazardous conditions during task execution. The smartphone and personal computer capture the parameter measurements in real time during rescue operation. The personal computer can record the measurements for emergency use too. It also reports the results achieved during the preliminary tests on the health monitoring device which uses to verify the performance of health monitoring device.

To further improve the reliability and accuracy of the results obtained for HMS, several recommendations are suggested as shown below:

i. The future experiments should include the skin temperature, posture and activity level.
ii. To improve the range of Bluetooth communication wireless protocol to have greater coverage for ease of communication during rescue operation.
iii. The future of this system should be test in field trials to validate the performance and reliability in real conditions.

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# APPENDICES

# APPENDIX A
# FEATURES OF BIOHARNESS 3

- Bluetooth Connectivity
- Configurable Output
- Heart Rate 25-240 BPM (±1 BPM)
- Breathing Rate 3-70 BPM (±1 BPM)
- IR Skin Temperature 10-60 ℃ (±0.1 ℃)
- Position/posture ±180 º
- Activity in VMU
- 3 axis Acceleration to 16g
- Skin Conductance Level
- Red/ Orange/ Green subject status indication
- Transmit and/or Logging Modes
- 250Hz ECG Logging
- 100Hz Accelerometer Logging
- USB connectivity for data download
- 570 hours data storage

# APPENDIX B

# SPECIFICATION OF BIOHARNESS 3

Unless otherwise stated : Temperature = 25 ℃, Pressure = 1 ATM

Power Supply : Internal Lithium cell, rechargeable via USB charging cradle or USB wall charger

| Parameter | Notes | Values | | | | |
|---|---|---|---|---|---|---|
| | | Min | Typ. | Max | Acc'y | Unit |
| **General** | | | | | | |
| Logging capacity | 1 | | 570 | | | hours |
| Power supply voltage | USB | 4.5 | 5 | 5.5 | | V |
| Battery Life - Radio transmitting | 2 | 9 | | 21 | | hrs |
| Battery Life - Logging | 3 | | 24 | | | hrs |
| Charging Time | | | 3 | | | hrs |
| Storage | Between charges | | 6 | | | |
| Charging Cycles | 4 | | 300 | | | Cycles |
| Digital resolution | | | 10 | | | bits |
| DC Input impedance | Between snaps | 20 | | | | MΩ |
| **Heart Rate** | | | | | | |
| Range | | 25 | | 240 | ±1 | BPM |
| Time to first lock | At 60 bpm | | 7 | | | s |
| No Signal Response time | 60 to 0 bpm | | 7 | | | s |
| ECG sensor sampling interval | | | 4 | | | ms |
| Input dynamic range | | 0.1 | | 10 | | mVpp |
| **Breathing Rate** | | | | | | |
| Rate range | | 3 | | 70 | ±1 | BPM |
| Breathing sensor sampling interval | | | 10 | | | ms |

**Operating Modes:**

Active - device transmitting data + logging, if configured

Standby - device not transmitting but connectable + logging, if configured

**Guaranteed Performance Cycle:**

New Battery - 21hrs Active / 3hrs Standby / 24hrs logging

After 1 year - 9hrs Active / 15hrs Standby / 24hrs logging

**Notes:**

1. General Logging (Gen + ECG = 140hrs, Gen + Acceleration = 280hrs)
2. Min Period – after 180 charge cycles. Max Period – new battery

3.Software required for data download.
4. After 300 deep discharge/charge cycles the battery will retain a minimum of 80% of its original capacity.
5. Min = device transmitting, Max = device logging

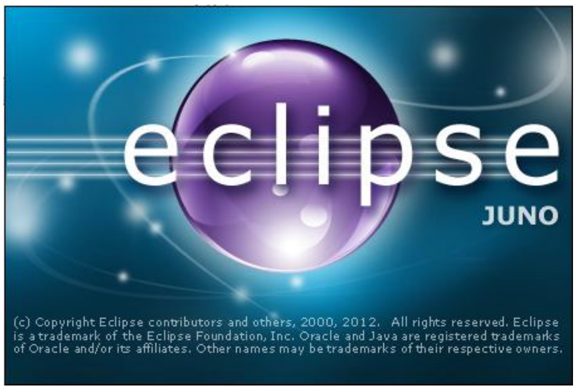
# APPENDIX C
# DATA TRANSMITTED OF BIOHARNESS 3

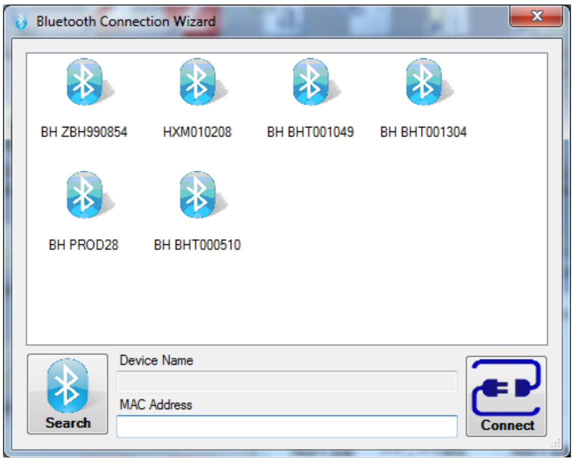
| Parameter | Reporting Frequency (Hz) | Range | Units | Description |
|---|---|---|---|---|
| **General Data Packet** | | | | |
| Heart Rate | 1 | 25 - 240 | BPM | Beats per Minute |
| Breathing Rate | 1 | 3 - 70 | BPM | Breaths per Minute |
| Skin Temperature | 1 | 10 - 60 | ℃ | |
| Posture | 1 | ±180 | Degrees | Vertical = 0 ° |
| Activity Level | 1 | ±16 | VMU (g) | |
| Peak Acceleration | 1 | ±16 | g | |
| Battery Voltage | 1 | 3.5 - 4.2 | V | |
| Breathing Wave Amplitude | 1 | | V | Indicative only |
| ECG Amplitude | 1 | | V | Indicative only |
| ECG Noise | 1 | | V | Indicative only |
| X Acceleration Min | 1 | ±16 | g | Vertical axis, output 1/10 g's |
| X Acceleration Peak | 1 | ±16 | g | |
| Y Acceleration Min | 1 | ±16 | g | Lateral axis |
| Y Acceleration Peak | 1 | ±16 | g | |
| Z Acceleration Min | 1 | ±16 | g | Sagittal axis |
| Z Acceleration Peak | 1 | ±16 | g | |
| ROG Status | 1 | R,O,G | | See section 3.4.2 |
| Strap Worn Status | 1 | 0,1 | | 0 = not worn |
| Device Button pressed status | 1 | 0,1 | | 0 = not pressed |
| Battery Percentage of Full Charge | 1 | 0 - 100 | % | % of full capacity |
| **Breathing Data Packet** | | | | |
| Breathing sensor output | 18 | 0 - 4095 | bits | Does not indicate breathing depth |
| **ECG Packet** | | | | |
| ECG Sensor output | 250 | 0 – 1024 | bits | For debugging purposes only<br>1 bit = 0.013405mV<br>Refence generated at 60bpm |
| **Heart Rate R-R Packet** | | | | |
| HR RR value | 18 | Minimum 250 | ms | Alternating ± sign at new detection |

Note: All data packets are time stamped in milliseconds.

# APPENDIX D

# TOOLS REQUIRED



# APPENDIX E

# GANTT CHART AND KEY MILESTONE

| | FYP I | | | | | | | | | | | | | | FYP II | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Week / Activities | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
| FYP Title Selection | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Literature Review | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Survey on Different Ways of integration between Sensors and Software | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Submission of Extended Proposal | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Product Quotation | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Proposal Defence | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Project Work Continues | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Submission of Draft Report | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Submission of Final Report | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Experiment on Product | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Submission of Progress Report | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Project Work Continues | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Pre-EDX | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Submission of Draft Report | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Submission of Final Report | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Submission of Technical Report | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| VIVA | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |