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Heartbeat Interval Variability Analyzer for Health Check-up

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ABSTRACT

The objective of this research is to construct a heartbeat detector based on the principle of blood flow on the finger tips which are correspondent to heartbeat rhythm. The infrared absorption technique is utilized and a computer interface is used to monitor the detection. Heartbeat wave forms are displayed on the computer screen and can be recorded for analyzing the wave aspects and heartbeat rhythm. Graphic equipment can be used to analyze the signals to focus on distance of heartbeats or heartbeat interval variability. The results on testing the detector's efficiency with twenty healthy male volunteers aged 22.35 ± 1.69, 73.80 ± 2.89 kg in weight, and 171.35 ± 3.44 m in height reveal that the "MY BEAT", a heart rate detector, is able to detect heart rates with about 3% error from a standardized detector. Our device from the volunteers' feedback, is also portable and easily implemented for recording heart rates while resting and after exercise training. Consequently, the MY BEAT can be used as a tool to analyze the heart rates changes and heartbeat interval variability preparation for basic health check-up.

Keywords: Exercise; Infrared absorption; Heart rate; Heartbeat interval variability

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1. Introduction

Heart rate is a variable indicative of the performance of the cardio-vascular system and a vital indicator of good physical health [1-6]. In general, it is used as an indicator for intensity of exercise or metabolic rate in conjunction with an assessment of training effects. Therefore, training types and duration should be selected to suit physical conditions of individuals, because good physical health enables the body to better endure fatigue. It is seen that those with good health or sportsmen have lower resting heart rate (RHR) than those who do not exercise. Furthermore, they are able to work longer hours. Good physical health is a result of regular and correct exercise or training [7]. For sportsmen, a training criterion is based on intensity of exercise to reach the target heart rate (THR), or 70%-80% of the maximum rate. For non-sportsmen, the target rate is approximately 60% of the maximum rate [8]. Heart rate variability (HRV) is the physiological phenomenon of variation in the time interval between heartbeats. It is measured by the variation in the beat-beat interval. Decreased heart rate variability is associated with increased mortality after myocardial infarction [1, 8]. Therefore, heart rate and heart rate variability are important for triggering health conditions.

2. Conceptual Framework

Heart rate is controlled by neurons of the cardiovascular center located in the medulla oblongata. Resting heart rate indicates the level of autonomous arousal. The level of arousal influences information processing. Resting heart rate helps to distinguish between poor and good deception detectors [1, 8]. Hence, the heart rate is an important physiological signal for assessing the health condition. It is possible to help the specialist preliminary to diagnosis and to give suggestions to prevent health problem. For this reason, to develop portable and low-cost heart rate detector and heart rate variability is to help people monitor their heart beat signal and become alerted when they have found an abnormal signal and get proper consultations from a physician. Heart rates are displayed in a graphic form, recorded and analyzed in order to correctly obtain heart rate changes of an individual while resting or during exercise training. Accordingly, the system design is proven to be safe for humans from electrical shock hazards and provides analysis on critical parameters. Therefore, without any trouble, technical results can be obtained via different types of portable devices.

3. Background and Related works

An important problem found among training individuals is that they cannot realize their heart rate change while training in order to adapt the intensity of their exercise on spot. One particular method is to measure heartbeat rate, such as auscultation or touching radial or carotid artery and counting pulse rate [9-10]. Nevertheless, these methods are inconvenient during training because during this time body parts are moving, making heart rate detection erroneous. Presently, there are devices, such as heart rate monitor watches that are able to record heart rate per minute while training. Nonetheless, the result cannot be displayed in wave form of each beat. Previous study by Khuboonprasert [11] and his coworkers in 2003 designed an infrared heartbeat detector to detect continuous pulsatile wave of blood flow on the finger tips. However, the device cannot be analyzed in wave form of each beat. Similarly, an automatic heartbeat detector [12] and a heart rate monitor [13] report the heart rates count; however, they cannot display changes of heartbeat pulse or save heart rates in a desirable file in computer memory. In addition, a previous project in 2013 [14] aimed to study and create a heart rate monitor which people can easily manually measure. The results showed that there is noise in the system; thus, heart rate could not be counted and the necessary properties of electronic devices were suggested. It is thus imperative to design and construct a heartbeat detector that is able to display in wave form as well as to compare the difference of heart performance during and after training. It would enable an individual to make a decision to enhance the intensity of exercise on the spot in order to reach the target heart rate and to achieve various physical capabilities according to one's needs. Furthermore, the data on heart rate change while training with different levels of intensity can be analyzed to understand clearly and efficiently anatomical responses of the cardio-vascular system to training. Finally, this principle can be applied for primary healthcare and for recommending a training program to others in order to promote better quality of life. There are many commercial devices, but they still have the limitation to display, record and analyze in wave form each beat at real time situation. To sum up, this investigation aims to construct a heartbeat detector that is able to display results in wave forms, save into a file with ASCII data, and analyze changes of heart rate accurately. Nowadays, personal computers are widely used in state and public health service agencies. All computers are now equipped with universal serial buses (USB), making it convenient to connect them with external devices. The concept is to design and construct a digital heart wave detector by adding special hardware to a personal computer, functioning as a receiver of heart rate changes and connecting it with a USB. It is based on the principle that a blood cell is able to absorb an infrared ray. The device detects changes of human heart rates by using a continuous pulsatile wave detector to detect blood flow at finger tips or the skin that corresponds with and relates to heart performance.

4. The Design

The design and construction of the device incorporates computer hardware that can detect signs of heart rate changes and is connected with a USB. The signal detector is composed of an infrared source bulb and an infrared sensor as a receiver to detect continuous pulsatile waves of the blood flow that corresponds to changes of heart rate. A computer program is designed to convert the waves into numerical and graphic forms and display them on the computer screen as shown in Fig. 1. This practice would enable users to know the changes while resting and during training. They can be saved into a file in the computer in order to analyze or report later. Moreover, they can be compared with changes before or after carrying out a daily activity.

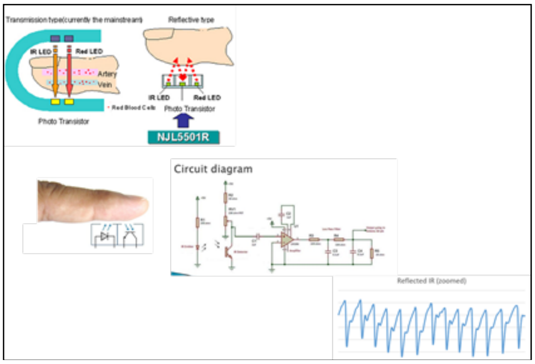

Fig. 1. Diagram design and heartbeat waveform signal.

4.1 The hardware design

The development steps of the infrared (IR) source circuit are based on the IR LED to project the IR ray onto the finger tips with blood flow in the skin. The IR sensor in the circuit reflects LED. The electric signals are filtered with a capacitor to filter out DC signals before returning them to the circuit. The circuit then converts analog to digital signals at the sharpness of 12 bit. The signals are then converted into the data that are transmitted to a notebook computer via a USB interface, which is controlled by the constructed computer program, Labview version 7.1. The program reads the values of the electrical signals from the NI-DAQ mx circuit as well as analyzes the signals of the heart rate.

4.2 The software design

The DAQ Assistance program is used to read electrical signals that indicate heart rate. Signal input is in millivolts (mV) with the maximum value of 500 mV and the minimum value of -500 mV by means of terminal configuration in different modes. The sampling rate for data reading is set at 25 kHz and, for the number of data for each reading, the sampling rate is set at 5000 data. After that, the data are gathered by a collector program to transmit them to the processing memory. Electrical signals of heart rate are transmitted to a filter program in order to filter out high-frequency interfering signals from the main signals by utilizing a low-pass filtering type. The cut-off frequency is set at 20 Hz and the Butterworth filtering type, order 5, is selected. The filtered electrical signals are fed into a sub-program to display them in a wave form or pulse according to heartbeat pulse. The graphic representations of heartbeat signals are shown in Fig. 2.

Fig. 2. The graphic representations of heartbeat signals from Configure Filter Program.

After opening the program, the main control program will appear as shown in Fig. 3a-b. When inspecting the data, the electrical signals are continuously collected for one minute and the heartbeat pulse is displayed in the collected heartbeat signal graph. While detecting the heart rate, the Threshold Peak Detector is used to count signal levels of interest. The counted signals must be higher than the designated threshold value. Counting the heart rate increases to one minute, which is the value of heart rate per minute or heart rate in the Count column. The counted data are then fed to a program and displayed in meter, called Heartbeat Rate (pulse/sec). If the saved data have too many interfering signals and we need to start anew, the Reset command is used to delete existing data. Then, a new data collection can start. The Save command is used to run the write-wave-form program and a new file name is established and saved into the computer memory.

4.3 The data analysis

The recorded data must be retrieved by using the "Load" command to run the Load wave form program. After the data are retrieved, they are graphically displayed in the Analyzed Heartbeat Signal, which enables us to read the heartbeat rate (pulse/sec) in the Count column as shown in Fig. 3b. The Threshold value must be appropriately set in the circuit program. The graphic tool can be used to expand the signals waveform in Y-axis and X-axis as shown in Figs. 3c-3d. The heartbeat waveform can analyze the signals by using the "Bring to Center" command to run the markers for measuring the two or three heartbeats interval variability, as shown in Fig. 3e-3f.

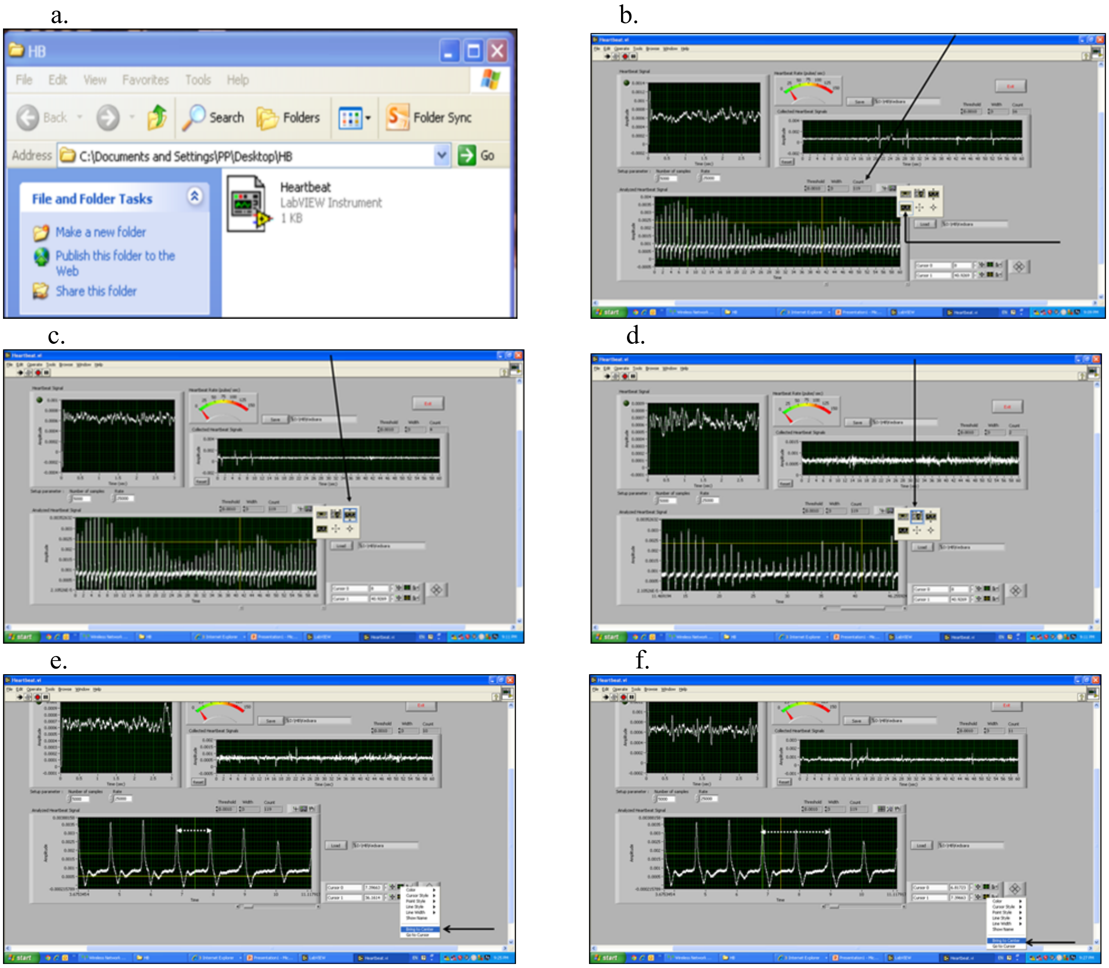

Fig. 3. The program of MY BEAT and detail.
a. The program of MY BEAT
b. record the heartbeat waveform count
c. amplify the heartbeat signals in Y axis
d. amplify the heartbeat signals in x axis
e. analyze the two heartbeats interval variability
f. analyze the three heartbeats interval variability

5. Design Results

Our results on the design and construction of the heart rate detector, named MY BEAT, are shown in Fig. 4.

The unique functions of MY BEAT

The MY BEAT possesses the following properties.

1. It can detect heart rate from the finger tips with blood flow in correspondence with heart beat rhythm during and after training.
2. It can display changes of heartbeat pulse on the computer screen in the Heartbeat Signal column while detecting and continuously displaying a one-minute duration in the Collected Heartbeat Signal column.
3. It can display heartbeat meter and count on the computer monitor.
4. It can save heart rates in a desirable file in the computer memory.
5. The wave form of the heart rate in the file can be analyzed in the Analyzed Heartbeat Signal column by using the analysis tools as follows:

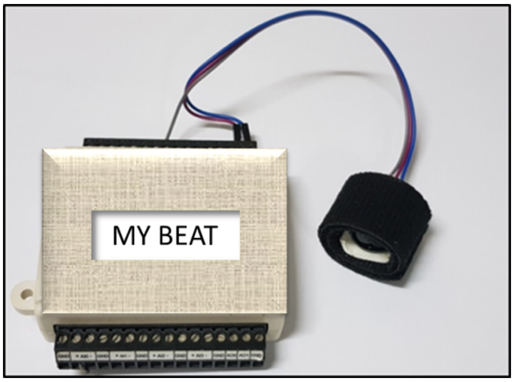

Fig. 4. The MY BEAT component records and displays the heartbeat signal.

- Wave form of the heart rate in a one-minute duration.
- The rate is in a count form with a time per minute unit.
- The wave form on the x-axis and y-axis can be expanded or focused on an area of interest.
- Distance of heartbeats or heartbeat interval variability can be compared in a time unit.

6. It is safe from electrocution due to the electricity supplying the detector coming from a 3-volt battery. The circuit and its parts, as well as electrical areas where users handle, are resistant to electricity, so there is no electrical leakage to the device.

6. Testing and Evaluation

To test the detector's efficiency, a comparison of the MY BEAT and the Heart Rate Monitor Casio Sport watch, CHR-100-1VDR model produced by CASIO Computer Co., Ltd, Japan, is conducted. The watch utilizes a chest strap to receive heartbeat signals and displays the count on its dial. The sample group was twenty healthy male volunteers aged 20 to 25 years. They regularly and continuously exercised three times a week for 20 minutes each time for at least six months. They had no abnormalities about their nervous, bone and muscular systems or acute illness or accident. The volunteers were selected from questionnaires before testing them. On average, the volunteers were 22.35 ± 1.69 years old, 73.80 ± 2.89 kg in weight, and 171.35 ± 3.44 cm in height. For testing their heart rate while resting and training, it was found that, while resting, the average difference in percentage points between the detector and the watch in mean ± standard deviation was 3.15 ± 1.12. During training, the average difference in percentage points was 3.18 ± 1.45, as shown in Table 1.

7. Discussion and Conclusion

The results of this study can be implemented to construct a heartbeat detector, MY BEAT, to detect and record heart rates and changes of heartbeat signals while resting and after exercise training. Nevertheless, this device is unable to directly detect heart rate during training, because body movements may bring about interfering signals, causing errors of heartbeat signal detection from the finger tips. It is thus recommended that the detection be carried out immediately after completing the training. Results from testing the efficiency of the detector reveal that the display of heart rate are not different from that of general heart rate monitor watches. The results reveal that the average difference during exercise training was 3.15%. These findings are similar to efficiency test results of a detector by Hashem [15] and his coworkers, who designed and constructed an infrared heartbeat detector to detect continuous pulsatile wave of blood flow on the finger tips. It was found that the detector was able to correctly detect heart rate at a certain level with an average error of 0-3%.

However, the results are not different from their study results, which constructed an automatic heartbeat detector [12] and wireless electrocardiography [16]. They reported that heart rates of the sample group detected by the automatic detector were approximately 1-2 % different from those detected by an electrocardiogram (ECG). In this investigation, intensity of exercise among the volunteers was at a submaximum level. It was found that their heart rates during training were at 120-130 beats per minute. It can be stated that this constructed detector is able to detect and record heart rates and changes of heartbeat signals while resting and during exercise training at the submaximum level.

This MY BEAT is able to detect heart rate with about 3% error from a standardized heartbeat detector. It can also be incorporated to detect and analyze heartbeat interval variability. The satisfaction rating results from the twenty volunteers show that the MY BEAT is able to instantly display results on the computer monitor and record them in a data file for later analysis and display. Furthermore, it can be used to plan an exercise program suitable for a particular individual. To wrap it all up, it is portable and easily implemented for recording and analyzing changes of heart rates and heartbeat interval variability preparation for basic health check-up.

Table 1. The heart rate signal at rest and after exercise training measured by the Heart Rate Monitor Casio Sport watch, CHR-100-1VDR compared with "MY BEAT" in 20 healthy male volunteers.

				Heart rate (beat/min)					
No. of Subject	Age (year)	Weight (kg)	Height (cm.)	Rest			After exercise training		
				CHR-100-1VDR	My Beat	% difference	CHR-100-1VDR	My Beat	% difference
1	20	70	175	78	80	2.56	122	124	1.64
2	22	70	165	84	80	4.76	120	124	3.33
3	23	77	170	80	78	2.50	122	120	1.64
4	25	70	176	76	80	5.26	120	124	3.33
5	22	72	170	78	82	5.13	124	126	1.61
6	21	70	165	78	80	2.56	121	126	4.13
7	24	75	170	80	78	2.50	120	124	3.33
8	21	76	176	84	80	4.76	124	126	1.61
9	20	77	170	80	78	2.50	122	126	3.28
10	22	77	177	78	80	2.56	126	128	1.59
11	23	70	172	78	80	2.56	120	126	5.00
12	25	72	171	78	80	2.56	122	120	1.64
13	22	70	175	80	78	2.50	120	124	3.33
14	21	75	170	84	82	2.38	124	126	1.61
15	24	76	168	80	78	2.50	122	126	3.28
16	21	77	169	76	80	5.26	120	128	6.67
17	20	75	172	78	80	2.56	120	126	5.00
18	22	76	171	78	80	2.56	122	126	3.28
19	24	75	175	80	78	2.50	120	124	3.33
20	25	76	170	81	83	2.47	120	126	5.00
Mean	22.35	73.80	171.35	79.45	79.75	3.15	121.55	125.00	3.18
SD	1.69	2.89	3.44	2.37	1.45	1.12	1.79	2.10	1.45

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References

[1] Jonathan KE, Paul MG, SV Paul, Steven JK. Clinical Exercise Physiology. 2nd ed.: Human Kinetics, 2009.

[2] Rakpongsiri K, Sawangkoon S. Increased myocardial energy reservation by creatine supplementation and estrogen replacement in exercise-trained ovariectomized hamsters. Asian Biomed. 2008; 2(1):71-6.

[3] Rakpongsiri K, Sawangkoon S. Increased myocadial energy reservation by two-week creatine supplementation. STA. 2009; 14(3):25-33.

[4] Leeuwenburgh C, Heinecke JW. Oxidative stress and antioxidants in exercise. Curr Med Chem. 2001;8:829-38.

[5] Rakpongsiri K, Sawangkoon S. Protective effect of creatine supplementation and estrogen replacement on cardiac reserve function and antioxidant reservation against oxidative stress in exercise-trained ovariectomized hamsters. IHJ. 2008;49:343-54.

[6] Rakpongsiri K, Sawangkoon S. Increased serum IGF-I level by creatine supplementation and estrogen replacement in exercise-trained ovariectomized hamsters. TMJ. 2009;9(4):337-45

[7] American College of Sports Medicine. ACSM's guidelines for exercise testing and prescription. 8th ed. Philadelphia: Lippincott Williams & Wilkins, 2009.

[8] Karlman W, James EH, Darryl YS, William WS, Brian JW. Principles of Exercise Testing and Interpretation: Including Pathophysiology and Clinical Applications. 4th ed. Philadelphia: Lippincott Williams & Wilkins, 2005.

[9] Vivian HH. Advanced Fitness Assessment and Exercise Prescription. 5th ed. USA, IL: Human Kinetics, 2006.

[10] McArdle WD, Katch FI, Katch VL. Exercise Physiology: Energy, Nutrition, & Human Performance. 6th ed. Philadelphia: Lippincott Williams & Wilkins, 2007.

[11] Khuboonprasert S. Heart rate monitor, Dissertation, Department of Electronics Technology (Instrumentation and Control), King Mongkut's Institute of Technology North Bangkok, 2003.

[12] Tipkam K, Maprasop J, and Thungmungmee S. Construction a heart rate monitor automatically. Independent Research, Department of Cardio-Thoracic Technology, Faculty of Allied Health Sciences, Naresuan University, 2007.

[13] Sriladloa T, Kornkaewwattanakul W. Heart Rate Monitor, The Prototype Electronics, [Online] [cited 2019 Jan 23].Available:http://www.es.co.th/Schemetic/PDF/HEART-RATE.PDF.p.1-7.

[14] Kambai J, Kotvichai S. Heart rate monitor. Engineering student Project, Department of Electrical Engineering, Faculty of Engineering, Khon Kaen University, 2013.

[15] Hashem MMA, Shams R, Kader MA, Sayed MA. Design and development of a heart rate measuring device using fingertip. International conference on computer and communication engineering, 2010.

[16] Rakpongsiri K, The Wireless Electrocardiography through the Computer Global Network. STA. 2016;21(2):25-33