

# Prevention and Risk Reduction in Heart Health

B. Kaminska, K. Tavakolian, B. Ngai, Y. Chuo, A. Vaseghi and B. Carmichael

Computational and Integrative BioEngineering Research Lab (CIBER)

Simon Fraser University and Adigy Canada

Kaminska@sfu.ca

## ABSTRACT

Identifying early onset of cardiac disease is not easy and it is very expensive. For this reason the first symptom of cardiac problem is often catastrophic. It is the goal to produce a screening device that effectively identifies the presence of the disease early which will allow the patients to take corrective action in lifestyle, behaviour changes diet and stress management in order to eliminate the need for surgical intervention and drug therapy. We adopt a new focus – studying changes in previously unobserved symptoms in order to detect sign of heart disease early on.

**Keywords:** Heart monitoring, new sensors, assessment algorithms, heart mechanical performance.

## 1 INTRODUCTION

Based on our pilot data (more than 100 subjects tested), we adopt an external monitoring and screening using mechanical (ballistocardiography) and electrical (ECG) heart assessment based on a new generation of electronic devices and computing techniques. *Ballistocardiographs (BCGs) can non-invasively detect heart issues before they have manifested on a noticeable scale.* Ballistocardiography is the study of the motion of the body with each heartbeat. Movements are thought to arise from myocardial contraction and the ejection and movement of blood from the heart to the periphery [1-3]. BCG waveforms are consistent for specific parts of the cardiac cycle [3]. The value of BCGs is that small changes in myocardial acceleration can be detected and such changes have been recognized as indicative in a number of cardiac abnormalities; most notably poor coronary perfusion. *Due to the recent software and hardware advances it is possible to identify the onset of some types of heart disease with a high degree of sensitivity and specificity using BCG analysis.* Diagnosis currently relies almost entirely on ECG, stress testing and imaging. While these tests are effective and used worldwide they are still expensive and have to be administered and interpreted by highly skilled medical practitioners.

Our research focuses on technology development and study of normal and abnormal BCG cases.

**Technology Development** - a new integrated micro-device has been developed and is in testing phase.

Extensive pattern creation and analysis is performed and compared to clinical test data, ECG, and imaging (echosound) test results.

**Study of Normal and Abnormal BCG Ranges** – In order to study a BCG signal assessment algorithm, data from healthy individuals as well as those with heart conditions are collected from people of all ages and backgrounds. Following the establishment of normal and abnormal signals it will be possible to identify at-risk individuals early on.

## 2 BACKGROUND

The ballistocardiogram is a vital signal in the 1-20 Hz frequency range which is caused by the movement of the heart and can be recorded by noninvasive means from human chest. It has been shown in previous research work [1] that the effect of heart malfunction can be identified by observing and analyzing the BCG signal. A number of clinical studies have been performed and specialized BCG instruments, including beds and chairs, have been developed by others [2]. However, there is still no practical and accepted BCG instrument nor analysis method available for clinical purposes.

Our research involves both the design of a new instrument and development of algorithms to acquire, analyze and classify the BCG signal. Such methodology will serve as a preventive screening tool for assessment of heart conditions. The focus of this paper is on new algorithms for BCG signal interpretation and classification. The proposed algorithms have been developed based on the literature, experimental studies and clinical tests.

The subject population includes different categories of elderly, youths, athletes and heart patients. BCG signals from 130 participants were recorded under ethical approval from Simon Fraser University and Fraser Health. During the data acquisition protocol, both the BCG and the electrocardiogram (ECG) are measured. The BCG signal is acquired using a seismographic device set up on the sternum and is synchronized with the respective ECG signal.

American Heart Association has assigned names to BCG waves. The letter H was assigned for the first upward deflection on the acceleration BCG following the electrocardiograph (ECG) R-wave when recorded

simultaneously. The letter G was assigned to the downward wave preceding H, while the letter I is the downward wave immediately after H, and lastly the letter J is the upward wave after I [3].

So far, different techniques have been used to acquire BCG signals. In [2], a BCG recording instrument is proposed which is commercially known as Bio-Matt, a static charge sensitive bed. This is essentially a wide plate capacitor set under a normal foam mattress of the patient's bed. In [8], a rigid piezoelectric force transducer resting on steel chair is proposed to gather the subject's

resting body movement including the BCG signal. The same chair structure is used in [10] for measurement of BCG using EMFi-film sensors. EMFi-film is an elastic, permanently charged, electret film material with the amount of charge changing according to pressure and is manufactured by Emfit Ltd. They have also used the same structure for development of a wireless BCG system [10].

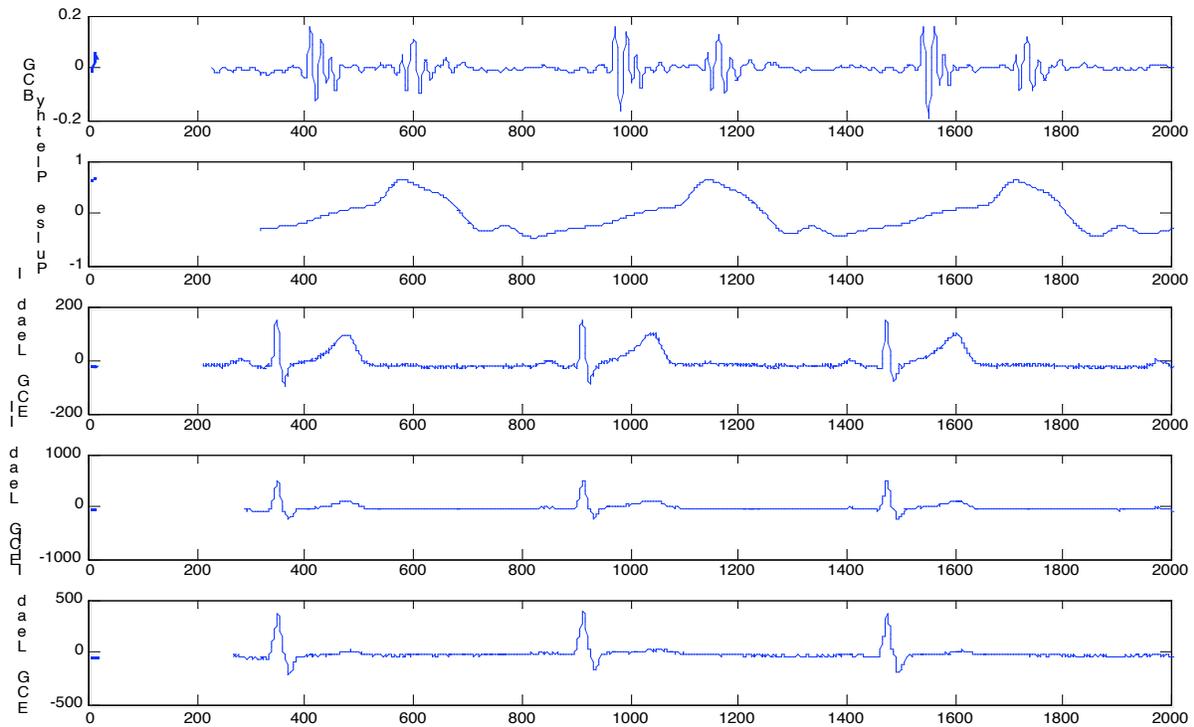


Figure 1. Sample data from clinical tests.

BCG in this research is obtained by placing an accelerometer on the sternum during quiet resting respiration. The accelerometer is factory calibrated, weighs 54g, and connects to a charge amplifier [3]. It is assumed that recording of BCG directly from sternum will have less noise and artifacts compared to the techniques explained previously and more closely relates to heart function.

### 3 ALGORITHMS

The following algorithm is proposed for studying the BCG signal in assessment of heart conditions.

- 1) The BCG signal is acquired together with one lead of ECG.
- 2) The R waves in ECG are detected and based on this detection heart contraction cycles are identified, and the averaged BCG signal for 1-one cycle is calculated from all cycles in the recording (i.e. 1min).
- 3) The averaged BCG signal is compared to individual beats. This comparison can be done visually or using signal processing methodologies.
- 4) If the averaged BCG is not representative of cycles, the signals are suspected to be related to arrhythmic cases as suggested in the classical Starr scheme [6].

**Table 1. The effects of different heart malfunctions on BCG and ECG signal.**

<i>Method</i>	<i>ECG</i>	<i>BCG</i>
<b><i>Ischemic Heart Diseases (IHD)</i></b>	-Hyperacute T wave (tall T) -ST segment changes -T wave inversion -Q wave longer than 0.04 sec -S in V1 and V2+R in V5 -R in I +S in III >25mm	-Increased amplitude in K,J,L,M (average amplitude is about 5mm) -Broad K wave -Fused H-J, especially during the expiration. -Notched J wave. -Q-I,Q-J,I-J changes
<b><i>Sinus Arrhythmia : Tachycardia, Bradycardia.</i></b>	-Typical ECG according to rate and P wave or QRS complexes.	-Prolonged HIJ complex. -Sometimes class III,IV (Star)
<b><i>Nonsinus Arrhythmia: -Ventricular and Atrial Flutter or Fibrillation</i></b>	-ECG shows different pattern According to P-QRS complex.	-Most of the time Class III or IV ( Star)
<b><i>Hypertension</i></b>	-Strain pattern. -T inversion -Large S or R., IHD changes	-Tall L wave. -Large H wave. -Fused H wave into J.
<b>Case 1</b>		Difference between consecutive cycles in Post-BCG resulting in average not representing the cycles. Risk factor: Age and Male
<b>Case 2</b>		The max of amplitude after exercise is less than max before exercise.

- 5) If the averaged BCG is representative of cycles, it is still possible for the subjects to have ischemic heart failures. In this case BCG signals are being evaluated in terms of the characteristics shown in the first row of Table 1.

## 4 RESULTS

Our proposed methodology involves two stages: initial signal acquisition from BCG, ECG, and pulse plethysmograph and the same signal acquisition after few minutes of exercise. Here are examples of the test data, Figure 1. The exercise was performed until one minute after the subjects reached 50% over their resting heart rate.

The three ECG limb-leads provided the R-wave temporal information which is synchronized with the BCG signal and used to identify each cardiac cycle. The BCG signal was bandpass filtered between 1-25 Hz and averaged to reduce background noise. Each averaged BCG signal is then normalized into a standard vector corresponding to the studied case. This procedure is applied to each data set for each studied participant.

The evaluation of different subjects helped to distinguish two abnormal cases which are listed in Table 1. In case 1 there was a distinct difference between the averaged BCG signal and the regular, un-averaged, BCG shape. In this case it was also observed that the pattern of BCG signal can be assigned to class 3 of Starr classification. In Case 2 which was observed in four subjects older than 75 years, the maximum of amplitude after exercise was less than maximum of amplitude before exercise.

We are able to classify the tested subjects into groups and identify the potential heard problems before ECG can record them. Figure 2a shows a case of a test results for a healthy individual before and after exercise. Figure 2b is for an abnormal subject with the significant differences when BCG is compared before and after exercise program. Such cases permit on the development of the classification procedure using BCG acquired together with ECG.

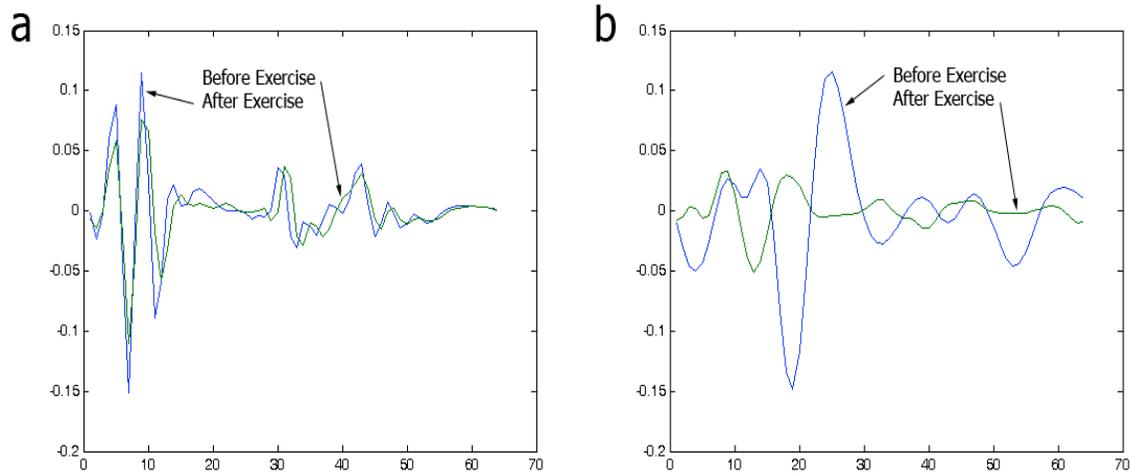


Figure 2. BCG signals collected from a healthy individual (a) and an individual who has cardiovascular disease (b) before and after exercise.

## 4 CONCLUSION

During our pilot study we have observed both normal and abnormal BCG signals. We conducted the validation of a new proposed classification algorithm as summarized in Table 1. We have identified cases that can not be identified by early ECG tests. This is the reason and motivation for farther continuation of the research in Ballistocardiography.

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