Developing an Android Application to Determine Short-Term Induced Heart Rate Variabilities

Leah Acquaviva, Emma Hindinger, Abdullah Albakr, Ying Sun, Ph.D.
Biomedical Engineering Program, Department of Electrical, Computer and Biomedical Engineering
University of Rhode Island, Kingston, RI 02881, USA. Correspondence email: yingsun@uri.edu

Abstract— **Monitoring of the heart rate variability (HRV) can be used to assess the viability of the autonomic nervous system. The portable device described in this paper allows for simplicity in home testing of HRV. By implementing a real-time QRS detection algorithm, the beat-to-beat heart rate (HR) is displayed on either the device's LCD screen or an Android smartphone/tablet via a Bluetooth wireless link. An IRB approved human study was conducted. The study protocol included two simple exercises to induce short-term HRV: the Valsalva maneuver and the sudden standing-up, each during a 15-s period. The preliminary result showed that the degree of HRV varied over a relatively broad range. The beat-to-beat HR had an increase trend during the Valsalva maneuver and an increase-then-decrease trend during the sudden standing-up. The HRV's between Valsalva maneuver and sudden standing-up were similar in range but very weakly correlated (r=0.13, n=10).**

Keywords—heart rate variability; Valsalva maneuver; sudden standing-up; human study; embedded system; Bluetooth; Android application

I. Introduction

Heart rate variability (HRV) is the variation of the beat-to-beat heart rate (HR) or the R-R interval, which is caused by the physiological regulation of the HR via the autonomic nervous system. For healthy subjects, HRV can be influenced by age, gender, body mass index and functional capacity [1]. Many studies have also shown that HRV is further affected by several pathophysiological and environmental factors [2]. HRV is determined over a time period typically between 5 minutes and 24 hours [3]. This study aims at the beat-to-beat trend of HRV during a very short time period, such as 15 s, induced by certain physical exercises.

The issue addressed in this study is the lack of a fast method to assess HRV with the ability to create an understanding of what this number informs us about our health. Fast determination of HRV is important because it can provide a simple indication of the individual's physiological condition. Self-monitoring of HRV has the potential to be a convenient and efficient way to check the health of an individual, especially through the use of a portable personal device. HRV can be established using induced breathing exercises as a method to change the HR like the Valsalva maneuver - attempted forceful exhalation against a closed airway. Previously, a prototype system was developed in our laboratory to facilitate such function [4]. In this project, the portable device was further improved to measure a single channel electrocardiogram (ECG), calculate the HRV, and transmit the data to an android device using a customized application through a Bluetooth wireless link. The users are able to see the trends of their own beat-to-beat HR on their mobile devices.

II. Methods

A. Instrumentation for the HRV Measurement

The block diagram of the system is shown in Fig. 1. The embedded electrocardiogram (ECG) monitor and QRS detector utilizes a customized ECG amplifier and a microprocessor (PIC18F4525, Microchip, Chandler, AZ). The real-time beat-to-beat QRS detection is accomplished by use of the multiplication of backwards differences (MOBD) algorithm [5]. The algorithm was programmed into the microprocessor by using the C language under the Microchip MPLAB X development environment. The program also implements a protocol to measure the beat-to-beat HR during a normal resting state for 15 s followed by an exercised testing state for another 15 s. The normal heart rate (HRn) is the average HR during the normal state. The tested heart rate (HRt) is the maximum HR during the exercised state. The induced HRV is given by: HRV (%) = (HRt – HRn) / HRn x 100%. A Bluetooth modem (blueSMiRF, Sparkfun, Boulder, CO) provides a wireless link at a rate of 115,200 bps to an Android smartphone or tablet. The ECG waveform as well as the beat-to-beat HR are transferred to the Android device for display and further analysis. An Android application was developed by use of the Android Studio integrated development environment (Google, Mountain View, CA).

B. HRV Trend Analysis

The device resulted from this project facilitates the study of exercise-induced HRV and the trend of beat-to-beat HR changes. The exercises used to induce this stress are the Valsalva maneuver and the sudden standing-up motion.

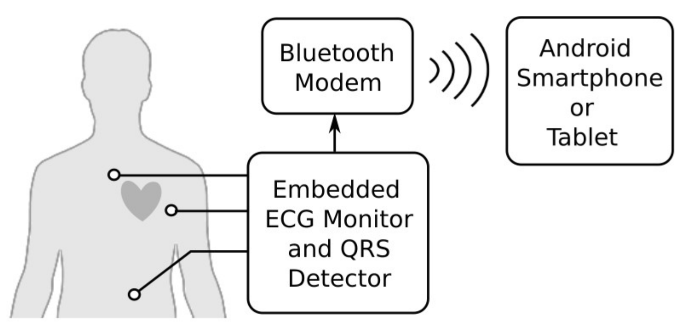

Fig . 1. Block diagram of the instrumentation.

C. *IRB-Approved Human Study*

A human study was conducted with the prior approval from the IRB. In addition to the demographic data, the ECG waveform and the beat-to-beat heart rate were recorded by the microprocessor unit and sent to the Android device for further analysis. The Valsalva maneuver was performed for 15 s. The exhalation pressure was not quantified, nor standardized. The subject was asked to attempt the maximum tolerable force. The sudden standing-up was a movement of standing upright quickly from a sitting position.

III. Results

The embedded instrument was successfully constructed, which incorporated a Bluetooth modem for communicating with an android device. A switch was implemented to direct the data display to either the LCD screen of the embedded instrument or the Android device. The 115,200-bps Bluetooth wireless link provided sufficient bandwidth to transfer the ECG waveform and the HR data to the Android device.

The IRB human research study has been on-going. The preliminary result was obtained from ten (10) anonymous volunteers, as shown in Table I. In the Valsalva maneuver case, HVR = 19% ± 8% (mean ± SD), ranging from 8% to 37%. In the sudden standing-up case, HVR = 20% ± 8%, ranging from 9% to 33%. While the HVR showed similar statistics between Valsalva maneuver and sudden standing-up, the correlation between the two cases was very weak ($r = 0.13$).

Fig. 2 shows the trends of the beat-to-beat HR changes for Valsalva maneuver (top) and sudden standing-up (bottom). The HR was normalized with respect to the average resting HR. the degree of HRV varied over a relatively broad range. The beat-to-beat HR had an increase trend during the Valsalva maneuver and an increase-then-decrease trend during the sudden standing-up.

IV. Discussion

The contribution of this project is twofold: 1) developing an Android application for the analysis of the short-term induced heart rate variability, and 2) studying the trends of beat-to-beat heart rate changes during the Valsalva maneuver and the sudden standing-up. The embedded ECG monitor and QRS detector system proves to be an efficient and flexible platform for the front-end instrumentation. The Android based device further provides a powerful tool for waveform display and data analysis. The observed difference in the HR trends seems physiological: The Valsalva maneuver reduces the preload of the heart. Then, the reduced cardiac output activates the baroreflex and increases the heart rate. The suddenly standing-up directly reduces the arterial pressure and thus has a faster activation of the baroreflex.

TABLE I. Demographic and HRV data for the 10 subjects

Subject ID	Gender	Age	HRV (Valsalva)	HRV (Standing)
1	M	25	17 %	17 %
2	F	22	37 %	18 %
3	M	22	11 %	24 %
4	M	22	16 %	9 %
5	M	60	23 %	19 %
6	F	21	20 %	31 %
7	F	21	8 %	17 %
8	M	22	12 %	18 %
9	F	20	23 %	33 %
10	F	22	19 %	11 %

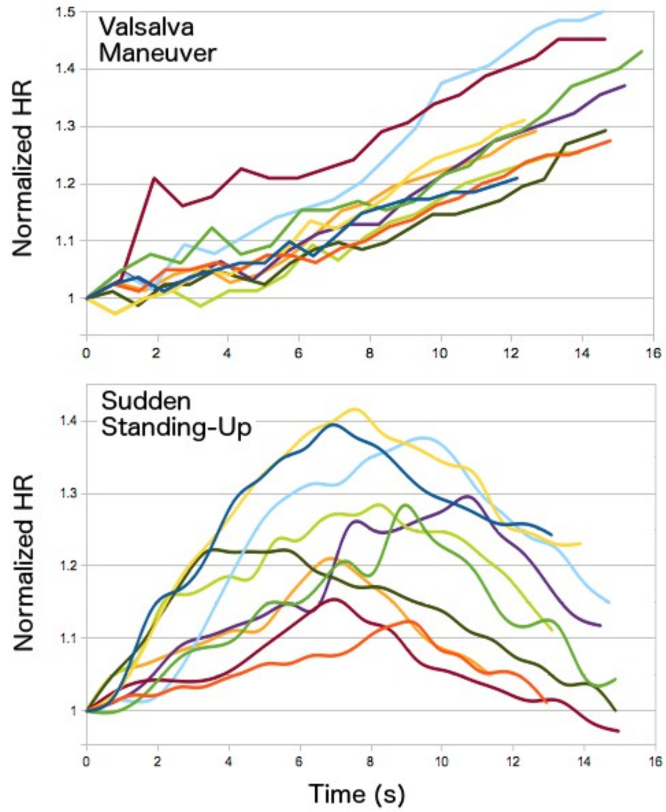

Fig. 2. Normalized beat-to-beat HR for the 10 subjects during the Valsalva maneuver (top) and the sudden standing-up (bottom).

References

[1] Antelmi, I., et al. “Influence of age, gender, body mass index and functional capacity on heart rate variability in a cohert of subjects without heart disease.” *American Journal of Cardiology,* vol. 93, pp. 381-385, 2004.

[2] Fatisson, J., V. Oswald, and F. Lalonde. “Influence diagram of physiological and environmental factors affecting heart rate variability: an extended literature overview,” *Heart Int.,* vol. 11(1), pp. e32-e40, 2016.

[3] Task Force of The European Society of Cardiology and The North American Society of Pacing and Electrophysiology. “Heart rate variability,” *European Heart Journal,* vol. 17, 354–381, 2006.

[4] Junkins, A., C. Thomas, E. Chabot, and Y. Sun. “Heart rate age: baroreflex sensitivity in response to Valsalva maneuver and sudden standing-up,” 42nd Northeast Bioengineering Conference, Vestal, NY, April 5-7, 2016.

[5] Sun, Y., S. Suppappola, and T. A. Wrublewski. “Microcontroller-based realtime QRS detection.” *Biomedical Instrumentation & Technology*, vol. 26(6), pp. 477-484, 1992.