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TABLE OF CONTENTS

TECHNICAL PAPERS

AUTHOR INDEX

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Measurement of Photoplythsmography signal for Heart Rate Variability and comparison of two different Age Groups

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***Abstract*—This paper investigates to compare the Photoplythsmography (PPG) signals based on Heart Rate Variability (HRV) criteria for two different age groups. This paper demonstrates the variation of PPG and HRV signals for subjects of age group in the twenties and fifties. The so used Easy Pulse Sensor module making use of the photo sensing technique to collect the amount of infra red light passing through the respective body part (finger tip in this case). After processing this signal through a series of condition stages involving low pass and high pass filter, a noise free PPG signal of adequate level is produced. The shape, frequency components and amplitude of this PPG signal depend upon the physiological condition as well age. This signal is then further processed by using the Arduino based processing board for being interfaced to a PC for display on the Graphical User Interface (GUI). The results are clear indicative of the physical conditions and age groups.**

Keywords—PPG; HRV; Optical sensor; Kubios; HRV

I. I. INTRODUCTION

Human blood carries oxygen along with other nutrients during its flow to different parts of the body. Physicians and doctors sometime need information regarding to the magnitude of oxygen to ensure the health of the heart, lungs and etcetera [1].Previously, the invasive method of measuring the oxygen concentration has been in use. However, recently the trends of non-invasive techniques are on the rise to replace the invasive techniques. This method is based on the principle that hemoglobin of the human blood absorbs the light signals.

The spectral behavior of the hemoglobin against different wavelength oflight rays is shown in Fig. 1 [1].

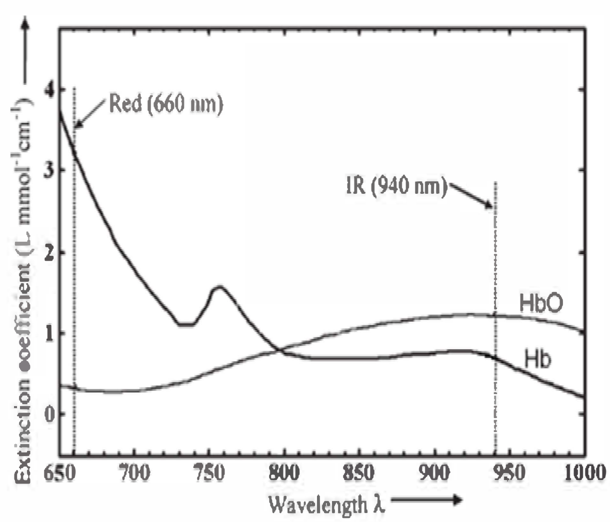

Fig. 1. Absorption spectra of Hb abd HbO [1].

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PPG is based on the idea that the body part where blood oxygen concentration is to be measured is subjected to two monochromatic light sources with the wavelength in therange of red and infrared light regions. The PPG signal detection is the resultant of the light either transmitted through or reflected from the body part [2].

The two types of PPG signal detection methods, which are PPGT (Transmission type PPG) and PPGR (Reflection type PPG) as shown in Fig. 2. PPGT is obtained from the extremities on parts of bodiessuch as the earlobes and fingertips where source and detectors are placed on the two parallel planes on the opposite sideswhereas PPGR is obtained from any part of the body placing the source and detector on the same side [3].

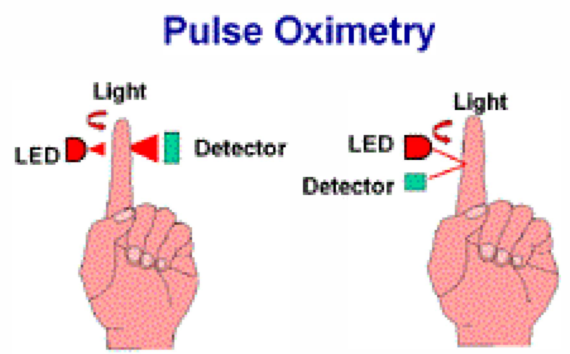

Fig. 2. PPGT (Transmission) vs PPGR (Reflectance) [8].

A PPG signal is composed of the three major components [4], namely:

i. The high frequency AC signal, representing the fluctuating arterial blood.
ii. The low frequency AC signal, that represents the fluctuations in venous blood.
iii. The DC signal, which signifies the PPG signal waveform for capillaries, bones and skin-color.

The three major components of the PPG signals relevant to AC and DC absorptions are as shown in Fig. 3

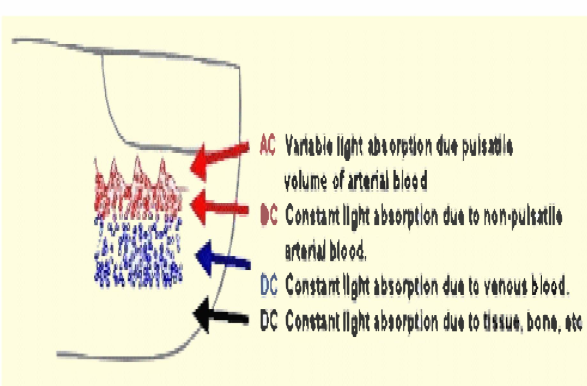

Fig. 3. Absorption of light due to multiple components in finger [9].

The compound PPG signal and its components described above are asshown in Fig. 4

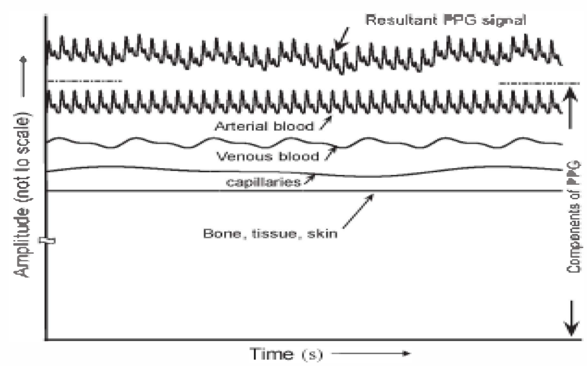

Fig. 4. Components of a typical PPG Signal [5].

PPG signal is being used to assess and monitor the cardiovascular healthcondition in clinics. Another non-invasive quantitative marker towards the cardiovascular health is HRV,which can be easily extracted from the acquisition of PPG and ECG signals [6].

It has been analyzed that the spectral difference of PPG signal remains for the person who is cardiovascular patient and the one who is normal healthy person.HRV can also be analyzed by using this PPG signal [7].

The separation of these high frequency (HF) and low frequency (LF) components is very important in order to have the information about Parasympathetic, Sympathetic and breathing conditions of the subject under study.

The influence of sympathetic and parasympathetic is represented by LF component of PPG signal as it is modulated by baro-reflex activities [10].

The High Frequency components represent the parasympathetic influence on the heart, and are linked with the Respiratory Sinus Arrhythmia (RSA), which is the cardio respiratory phenomenon that is characterized by the IBI fluctuations which are in phase with the inhalation and exhalation [11].

As the HF component of PPG signal is linked with the breathing, hence Respiratory Rate (RR) estimation can also be made by PSD of the HRV signal for the corresponding PPG signal. The center frequency of HF components shifts depending upon the variation in the RR [12].

II. METHODOLOGY

In the acquisition of PPG signal and its subsequent analysis the following steps are adopted.

A- PPG Signal Sensing and Generation.

An optical sensor placed on fingertips coverts information related to rhythmic pulsation of blood in to electrical signal. The so collected PPG signal is passed onto the Easy Pulse Sensor Module where it is conditioned by passing it through a series of the high pass and low pass filter circuits, making it noise free and of level adequate to be used for oxygen estimation. The frequency and level of this PPG signal is varying based on the four different physiological, that is, sitting, standing, laying and jogging as well as depending on the age factor.

B- Signal Processing and Communicating Unit.

Arduino processing module is used to process the PPG signal it receives from the output of Easy Pulse Sensor. Hence, Arduino module is used as bridging device for transferring the wave shapes,and data from Easy Pulse Sensor to the PC- the Arduino processor and PC are both programmed and interfaced for the purpose of intended PPG wave shape and data.

C- Graphical User Interfaces.

Easy Pulse Analyzer and CoolTerm Graphical User Interface (GUI) are used to get the wave shape and data respectively for the corresponding (as the nominal range of LF components is 0.04 – 0.15 Hz and HF component is 0.15 – 0.4 Hz) PPG signal. Later, this each PPG signal is analyzed by using Kubios HRV software in order to have correct values of HRV, LF/HF ratio representing the given physical and age group conditions of the subject concerned whose PPG signal is under question.

III. EXPERIMENT AND RESULTS

We have managed to take the PPG samples of four of volunteer subjects from each age group, that is, four volunteers from the 20-30 age group and four volunteers from the 50-60 under in all four different physiological condition (sitting, standing, laying and jogging). For each subject we get each PPG wave form and data for each physiological conditions, we got four PPG signals and data for each subject of each group. The so obtained PPG signals for 20's in sitting and jogging conditions are as shown in Fig. 5(a) and (b). Each Easy Pulse Analyser window represents the BPM (Beats Per Minute), ADC sample rate (which it adjusts automatically) and Samples in 5msec time interval.

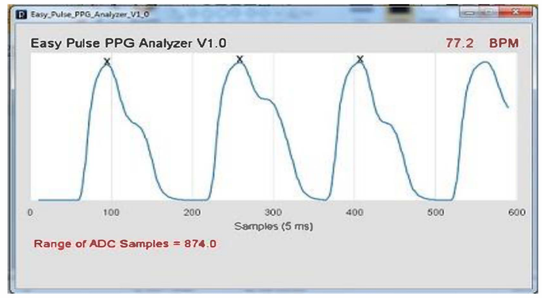

Fig. 5(a). Easy Pulse displaying waveform for sitting condition.

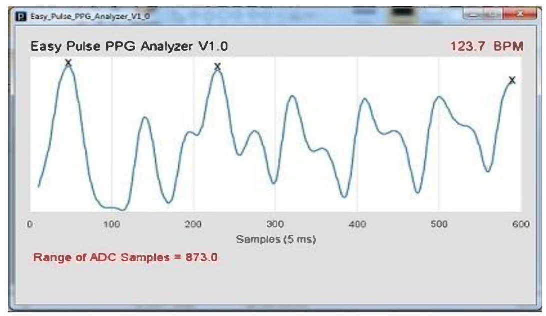

Fig. 5(d): Easy Pulse displaying waveform for jogging condition.

Similarly the PPG signals obtained from the 50's in all four different physiological conditions, that is, sitting, standing, laying and jogging. The PPG signal for the standing and laying are also shown in Fig. 6(a) and (b).

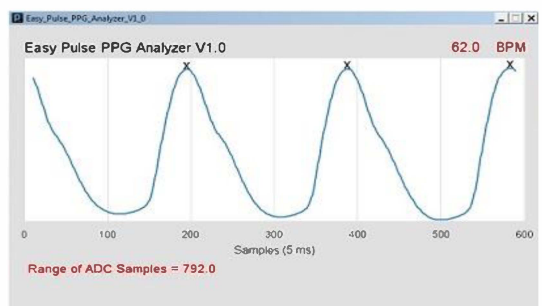

Fig. 6(a). Easy Pulse displaying waveform for standing condition

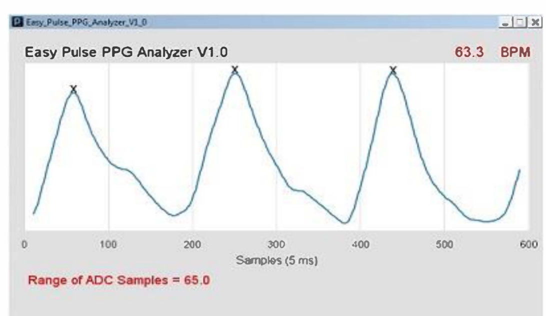

Fig. 6(b) Easy Pulse displaying waveform for laying condition.

The CoolTerm windows representing the acquisition of the data is shown in Fig. 7

Fig. 7. CoolTerm displaying data window.

In order to Analyze and get the HRV, LF, HF and LF/HF values we used Kubios HRV Software. It generated these values for each physiological conditions of each person. Hence we got four different graphs and values for each subject. The comparing windows of Kubios HRV for a subject in 50's and 20's in four different physiological conditions (sitting, standing, laying and jogging) were analyzed. The Fig. 8(a) and (b) represent the PPG analysis results for 50's in standing and laying conditions where as Fig. 9(a) and (b) represent the PPG analysis results for 20's in sitting and jogging conditions. The window of Kubios HRV represents the analysis of PPG signals.

a) In time domain where it shows its parameters likes Mean RR (Respiratory Rate), Mean HR (Heart Rate) and many others parameters.

b) In frequency domain where it generates the corresponding PSD (Power Spectral Density) for each of PPG signal and AR spectrum estimation results for the same PSD. Actually the main advantage of AR modeling is that it yields improved resolution results especially for the short signal.

c) Non linear representation of the PPG signal which is the Poincare plot. It is a graphical representation of the correlation between successive RR intervals, i.e. plot of RRj+1 as a function of RRj. The second plot in Non linear representation is the Correlation dimension. The correlation dimension is expected to give information on the minimum number of dynamic variables needed to model the underlying system.

50's Age Group Sample Results

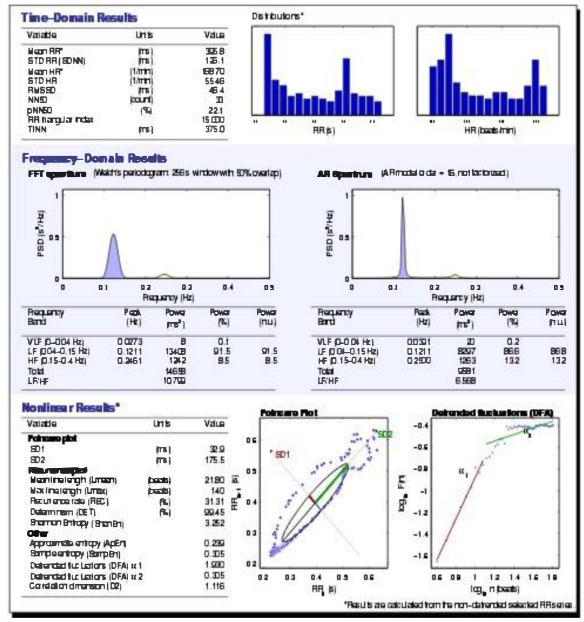

Fig. 8(a). Kubios HRV software window standing condition analysis of PPG signal

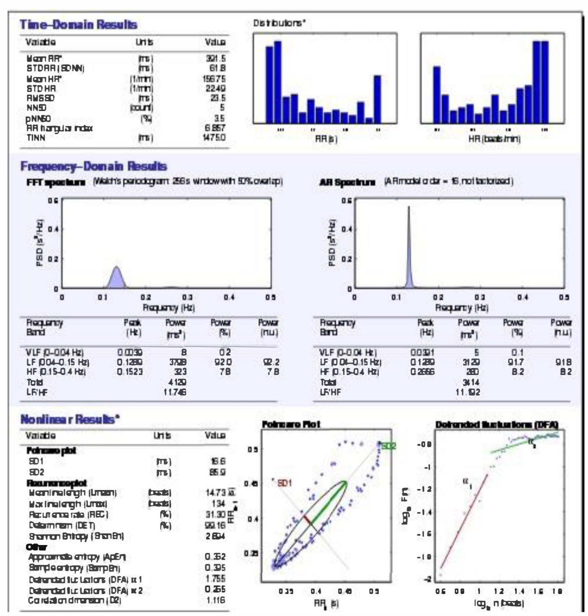

Fig. 8(b). Kubios HRV software window laying condition analysis of PPG signal

20's Age Group Sample Results

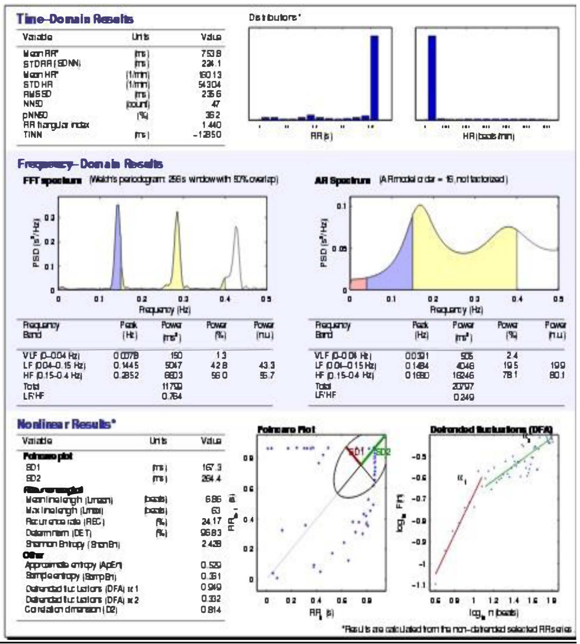

Fig. 9(a). Kubios HRV software window sitting condition analysis of PPG signal

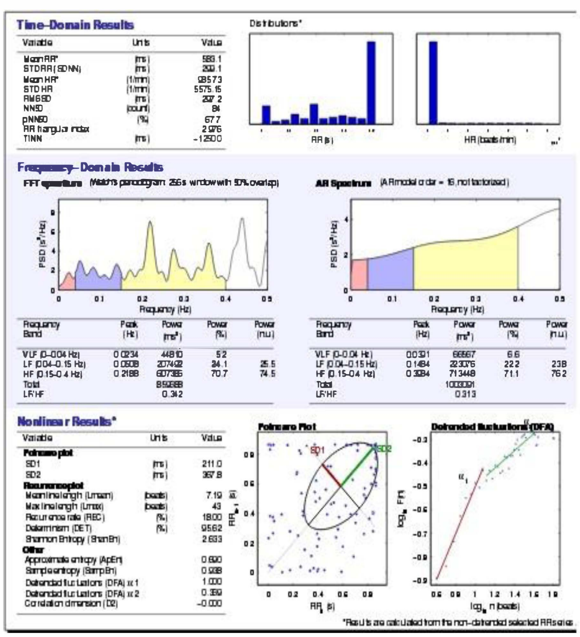

Fig. 9(b). Kubios HRV software window jogging condition analysis of PPG signal

We got these HRV, LF, HF and LF/HF ratio for four volunteers between the age 20-30 and four from 50-60 year age and tabulated the results obtained in Table-IA, IB and Table-IIA, IIB. The value Table-IA and Table-IIA represent the change of LF/HF and HRV components with the transition of the subject from the sympethetic condition to parasympethetic condition.

The Table-IB and Table-IIB represent the details of the examined subjects in terms of sex, age, region and physiological conditions.

TABEL IIA. LF/HF and HRV for the 20-30 years.

SR NO	SITTING CONDITION		STANDING CONDITION		LAYING CONDITION		JOGGING CONDITION	
	LF/HF	HRV	LF/HF	HRV	LF/HF	HRV	LF/HF	HRV
SUBJECT.1	0.22	227.59	0.04	353.79	0.007	148.5	0.24	967.39
SUBJECT.2	0.06	717.39	0.24	361.74	0.04	371.95	0.09	235.95
SUBJECT.3	0.577	85.02	0.091	359.62	0.634	192.37	0.301	584.33
SUBJECT.4	0.224	143.00	4.180	150.85	0.290	852.13	0.372	267.94

TABEL IB. Details of the Subject of the 20-30

SR NO.	(M/F)	AGE	REGION	PHYSIOLOGICAL STATE
SUBJECT 1	M	21	SOUTH INDIA	ALL 4 STATES
SUBJECT 2	M	24	SOUTH INDIA	ALL 4 STATES
SUBJECT 3	M	25	SOUTH INDIA	ALL 4 STATES
SUBJECT 4	M	26	BANGLADESH	ALL 4 STATES

TABEL IB. LF/HF and HRV for the 50-60 years age

SR NO	SITTING CONDITION		STANDING CONDITION		LAYING CONDITION		JOGGING CONDITION	
	LF/HF	HRV	LF/HF	HRV	LF/HF	HRV	LF/HF	HRV
SUBJECT.1	4.57	460.25	2.21	327.81	0.4076	447.30	0.204	719.54
SUBJECT.2	0.031	253.37	0.106	583.32	2.144	478.39	0.021	566.7
SUBJECT.3	2.117	151.98	0.278	487.05	2.503	165.01	0.340	513.74
SUBJECT.4	20.974	152.56	10.799	168.70	11.746	156.75	0.667	782.61

TABEL IIB. Details of the Subject of the 50-60

SR NO.	(M/F)	AGE	REGION	PHYSIOLOGICAL STATE
SUBJECT1	M	56	PAKISTAN	ALL 4 STATES
SUBJECT2	M	50	BANGLADESH	ALL 4 STATES
SUBJECT3	M	59	PAKISTAN	ALL 4 STATES
SUBJECT4	M	55	MALAYSIA	ALL 4 STATES

IV. CONCLUSION

It is concluded that the pulse width tends to be increasing with age. With age, the arteries become less distensible, ultimately resulting into rounded PPG having a lack of notch, which in turn, decreases arterial compliance. Also, the high frequency components become less with the increase of age in subjects. It shows that the analysis of PPG contours offer new technological development in the invasive circulatory monitoring of blood and blood-related health complications.

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