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CBView: Merging Data in Metabolic Diagnosis

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Abstract

The metabolic syndrome is a set of risk factors associated with increased cardiovascular risk. These changes to the standard metabolic functions are associated with increased blood insulin and with insulin resistance, which is the common feature of disease pathophysiology. Although with admissible genetic inheritance, the metabolic syndrome symptoms increase with age, sedentarism, weight gain, tobacco, and poor dietetic habits.

Due to their characteristics, clinical manifestations of metabolic diseases are perceived by the patient at advanced stages of metabolic dysfunction, when the risk of an acute cardiovascular event is high. Early detection of disturbed glucose homeostatic mechanisms, by recording efferent responses to stimuli like meal ingestion, is, therefore, a methodology with diagnostic potential acting as a predictive measure of metabolic dysfunction.

This work presents a novel software (CBView) that analyses the records of physiological responses mediated by the carotid bodies to provocation tests, obtained by a new medical device (CBMeter) aiming to the early tracking of changes in autonomic responses that control metabolism, and thus providing quantitative metrics to assess metabolic dysfunction.

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1. Introduction

Metabolic syndrome, also known as insulin resistance syndrome, is clinically defined based on standard values of the abdominal perimeter, HDL cholesterol, blood glucose and hypertension. The diagnosis is made on the basis of analytical recordings, where the changes appear at a stage of considerable evolution of the underlying metabolic dysfunction [1].

The diagnosis of Metabolic Syndrome (MS) has consequences in triggering changes in the associated risk factors, and therefore, early diagnosis presents with a high potential in terms of prevention of cardiovascular diseases [2]. In animal models of MS, it was observed that the carotid bodies (CBs) are overactivated, causing an increase in sympathetic nervous system tone, underlying diseases such as obesity, hypertension and type2 diabetes (T2DM) [3]. This discovery provided a new paradigm for Neuroendocrinology, suggesting that diagnostic function of the CBs has predictive value for the development of metabolic diseases. Despite this fact, it is not common in clinical practice to look at the CBs as organs associated with endocrine dysfunction due to the difficult assessment of his function in an integrated way of test-response.

The CBs are classically looked at as peripheral chemoceptors that sense changes in blood gases and blood pH to evoke cardiovascular and respiratory responses that correct the changes detected to physiological levels [4]. Recently it was described that these organs also sense high insulin levels and thus may be involved in the genesis of the metabolic syndrome [5] [6]. Due to their nature of sensory organs linked to autonomic efferent responses CB activity may be measured by through a close-loop system by causing changes in the variables that are sensed by the carotid bodies and assessing the evoked cardiorespiratory and metabolic responses.

The CBMeter is a prototype developed by our group to be a user-friendly, portable and integrated device, conceived to assess CBs function, by measuring sympathetic and metabolic responses to stimuli. The device has two main modules. One to be used indoor, where controlled acute provocation tests are performed by health specialists (ingestion of meals whose nutritional content is controlled, or oxygen inhalations). The second component is a complementary one; integrated into the first component aiming to be used in continuous long-term recordings to test chronic changes to daily responses.

Given the nature of the data and also the system properties (biological signals from the human body) data analysis methodologies based on classical statistical measures or using the temporal domain will not meet the requested sensitivity. The characteristics of non-linearity and non-stationarity (considered together or isolated) are key data analysis of nonlinear systems (e.g the human body trying to obtain homeostasis). Therefore, we developed a software dedicated to the integrated analysis of cardiorespiratory and metabolic data acquired with the CBmeter, attemptatively named “CBView”.

The software version presented herein allows the execution of temporal studies and to perform analysis in the frequency domain. A later version will also account for studies in the time-frequency domain and also through tools of the theory of dynamic systems.

This paper is organized as follows: Section 2 describes the CBMeter signal analysis software in detail and Section 3 presents our results and conclusions.

2. CBView – CBMeter signal analysis software

In order to provide a tool to visualize, process and analyze the physiological signals acquired by the CBMeter system, an intuitive graphical user interface was developed. Therefore, doctors and medical technicians can easily extract relevant physiological information from the recorded data. To perform a screening test for carotid-body mediated metabolic disorders, using a minimum set of data, heart rate, respiratory rate, and blood oxygen level must be registered. The heart rate is computed from the electrocardiogram (ECG) signal and by using a single-lead differential sensor. This sensor consists of three surface electrodes placed on the chest and an electronic circuit to measure the electric activity of the heart. To record respiratory rate, a respiratory inductance plethysmography (RIP) sensor was used. It consists of a chest strap that is sensible to the displacements of the rib cage whose output signal is

used to compute the respiratory rate. Finally, a peripheral capillary oxygen saturation (SpO2) sensor was used to estimate the amount of oxygen in the blood. The SpO2 sensor is a small optical device with two light sources (red and infrared) that can be attached, using a clip, to the finger or the earlobe. All these sensors and the data logging system belong to BiosignalsPlux researcher kit developed by Plux [7]. The data was recorded at a sample rate of 500 samples per second.

In a future version, the CBView software will include the visualization and post-processing of the obtained data from other physiological sensors, for variables like body temperature, body motion, and glucose levels, that will be recorded using commercially available devices and whose integration will contribute to increasing diagnostic accuracy.

After the recording stage, it is necessary to extract relevant information from the acquired signals. The CBView is developed using MatLab environment to visualize and process the data. The software has an initial configuration tab and three other different tabs each one assigned to a different physiological signal: ECG, RIP and SpO2.

2.1. Configuration tab

The configuration tab is opened by default when the CBView program starts (Fig. 1). On the left side, there is a configuration area where the user can browse and open the desired recorded data file, define the interval of data to be analyzed and start the visualization and processing tasks. Also, it is possible to visualize the raw data within the selected time interval.

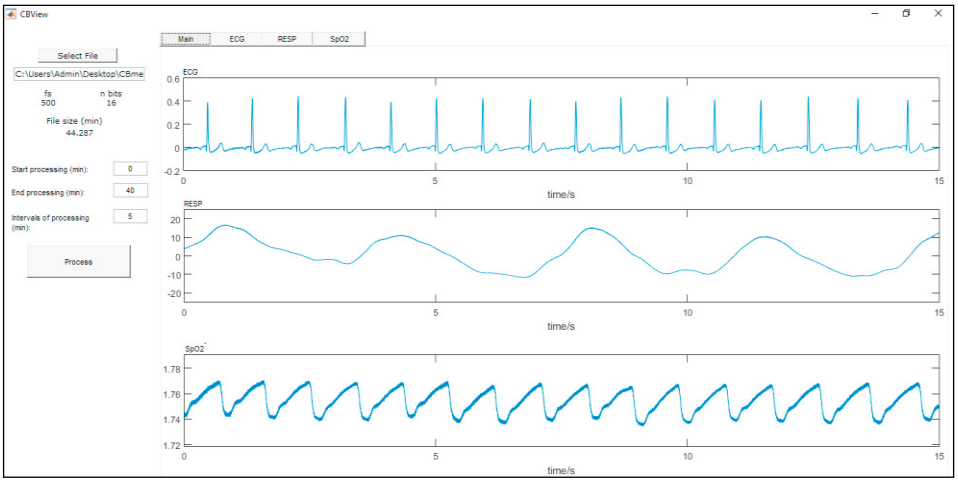

Fig. 1. CBView – Configuration tab. The first window displays the ECG recording; the second window displays the respiratory plethysmography recording and the third window displays the red light source signal from the oxygen saturation recording.

2.2. ECG tab

By selecting the ECG tab, it is possible to process the raw data from the ECG sensor. ECG signal processing task consists of computing the RR-intervals (interbeat intervals) to obtain the heart rate. The processing algorithm must deal with several issues such as baseline drift, motion artifacts (muscle contraction) and R peak amplitude variability. A band-pass filter is applied to remove the baseline drift (low-frequency component) and high-frequency components due to muscle contractions. Also, to cope with the R peak amplitude variability, an adaptative threshold algorithm was implemented. Fig. 2 illustrates a typical ECG signal with R peak detection, tachogram, heart rate variability and tachogram spectral analysis.

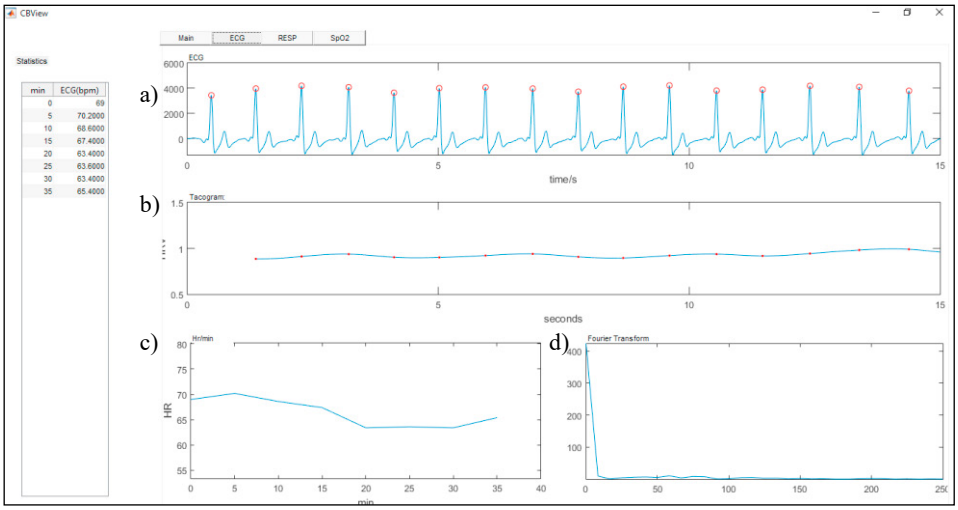

Fig. 2. CBView – ECG processed signal using CBView software: a) ECG with peak detection, b) tachogram, c) heart rate evolution and d) tachogram spectral analysis.

2.3. RIP tab

Regarding RIP tab, the user can see the output signal from the respiratory sensor. It is a low-frequency signal with lower amplitude as illustrated in Fig. 3. When computing the time between two consecutive peaks of the signal (inter-breath interval) it is possible to calculate the respiratory rate and the Respiratory Rate Variability (RRV).

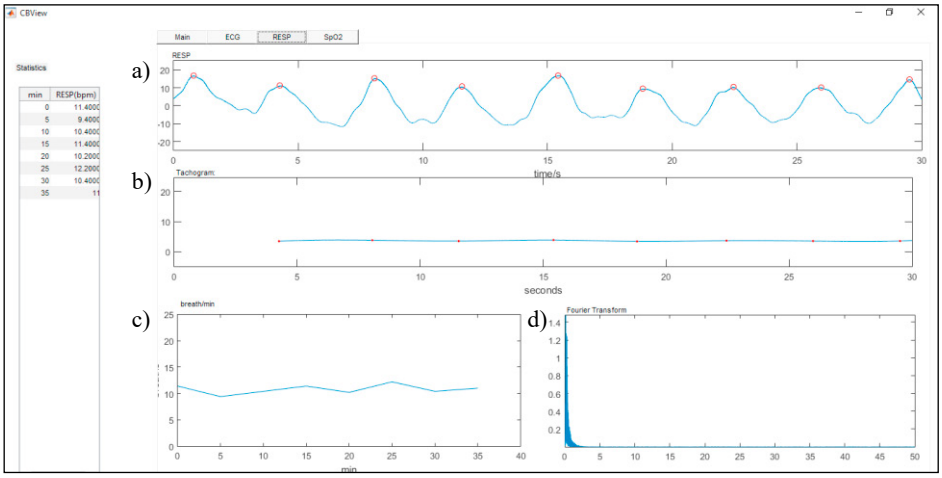

Fig. 3. CBView – RIP tab: a) RIP output signal with peak detection, b) tachogram, c) respiratory rate and d) tachogram spectral analysis.

2.4. SpO2 tab

The SpO2 sensor has two outputs from each light source (Fig. 4). According to the methodology presented in [8], the SpO2 value is calculated by computing the pulsatile and continuous components of both the red and infrared light sources. The pulsatile component is related to the blood volume variation that is responsible for changing the received light intensity and the continuous component is related to the tissues, bones and to the average blood volume.

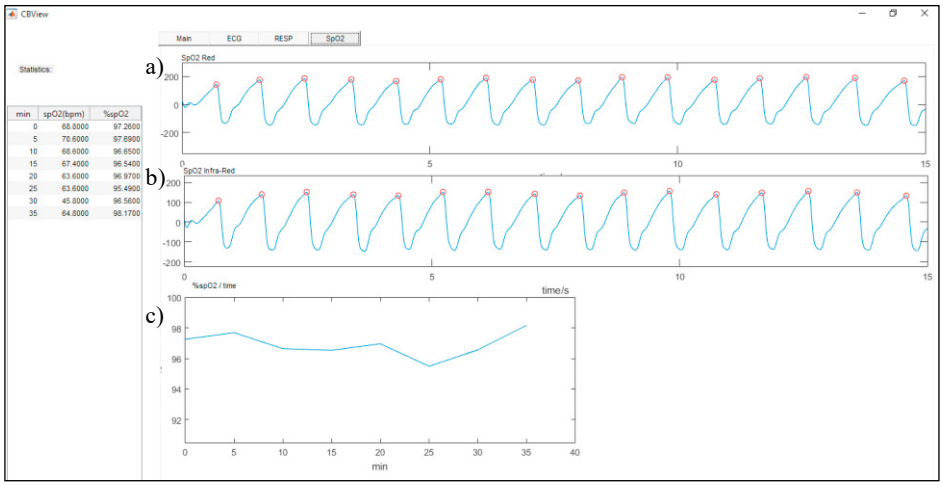

Fig. 4. CBView – SpO2 output signals: a) red source output signal, b) infra red source output signal and c) SpO2 evolution.

3. Results and conclusion

The CBView software is capable to present relevant information from the processed data. After processing the ECG signal (peak detection and time interval computation) it is possible to construct a Heart Rate Variability (HRV) tachogram that depicts the RR-interval evolution along time (Fig. 5 (a)). Spectral analysis of the HRV tachogram could be used to evaluate the influence of each subsystem constituting the Autonomous Nervous System (ANS), i.e. the sympathetic and the parasympathetic system (Fig. 5 (b)).

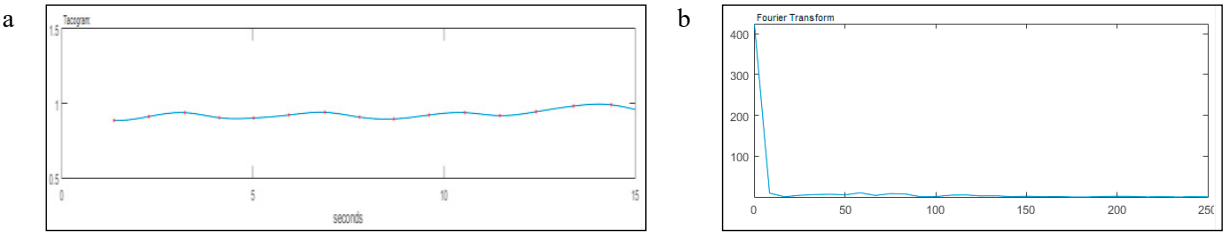

Fig. 5. (a) HRV tachogram; (b) HRV spectral analysis.

The RRV derived from the RIP output data is another valuable result. In Fig. 6 it is possible to see the respiratory rate evolution during the acquisition period.

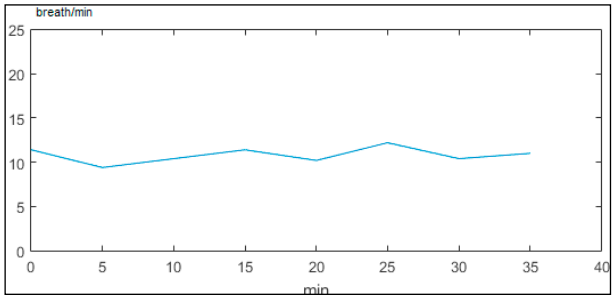

Fig. 6. Respiratory rate variability.

Another relevant clinical information is the SpO2 evolution. The CBView software provides a graph representing the blood oxygen level variation along time (Fig. 7).

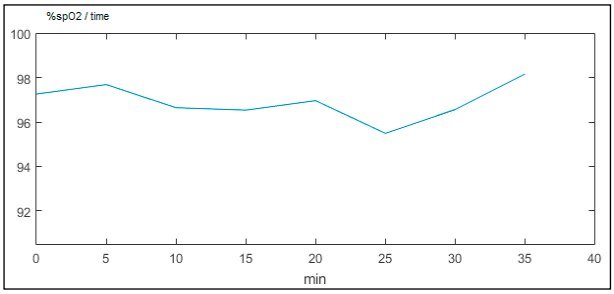

Fig. 7. Blood oxygen level evolution.

In conclusion, this work presents an initial version of the CBView software, which will be complemented in the following versions with additional functionalities regarding time-frequency domain processing techniques and chaos theory. The following versions are also predicted to integrate electrochemical signals and body temperature.

The software was developed in Matlab, however, it is intended in the near future to migrate to an executable program or a web based solution.

The resumed information of CB activation response patterns in target systems can be accessed using this software, by using graphical information which is a valuable tool to understand the evolution of cardiac, respiratory and gasometric parameters. This knowledge is the basis to metabolic diseases assessment, thus the integration of this information in a graphical interface is a key step for metabolic diagnosis.

Acknowledgements

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