TRABR: TRAINING INSULATED BREATHING USING PRESSURE SENSORS

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Abstract: Introducing TRABR (TRAining of BReath) for continuous monitoring of pulmonary ventilation during the patients' therapy and focuses especially on monitoring of their ventilation processes. It is necessary to detect, monitor and differentiate abdominal and thoracic breathing during the therapy. One of the methods for monitoring respiration is described, which was developed at BUT (DBME and DCI). Finally the game to practice breath was designed to evaluate whether the patient uses two types of breathing or not.

Keywords: Pulmonary ventilation, thoracic breathing, abdominal breathing, breath monitoring using pressure sensors, TRABR (TRAining of BReath).

1. INTRODUCTION

Breathing (pulmonary ventilation) is one of the physiological needs. These physical requirements essential for human survival must be met, otherwise the human body cannot function properly and will ultimately fail. An unhealthy lifestyle, continuous and immediate stress and rushing throughout our daily life are witnessed (among other symptoms) by incorrect breathing habits. Even though it is not usually fatal, in conjunction with other disorders it can lead to serious respiratory diseases. A detailed clinical examination may aid to diagnose incorrect breathing or other disorders; e.g. posttraumatic stress disorder (PTSD).

There are three basic types of respiration: abdominal, thoracic and subclavian. The lungs can be most emptied thanks abdominal breathing, resulting in better oxygenation of the body. Conversely, the lack of implementation of this type of breathing can result in a greater tendency to constipation, indigestion and hemorrhoids. Thoracic breathing is used to prevent heart disease and blood circulation.

The spirometry is basic method of examination ventilation. Its disadvantage is the use of problem mouthpiece or mask. Spirometry cannot distinguish isolated breathing. The examination is also dependent on patient compliance. Further examination depends on the patient's age. Diagnosis of the disease is often difficult in early childhood -young children are not able to cooperate. For these reasons, other methods are developed. These methods are completely non-contact or operate without problem with mouthpieces. These methods are based on detection of lung volumes or a shift in the chest or abdomen by various detectors.

Some research teams deal with respiratory inductive plethysmography (RIP) [1], [2], impedance plethysmography [3] and optoelectronic plethysmography (OEP) [4]. All methods are contact, rarely available and expensive. Abdominal and cardiac surgery can lead to pulmonary complications, which ultimately increase the demand and cost of healthcare. Postoperative breathing exercises can reduce pulmonary complications by encouraging deep breathing and improving lung function. The use of breathing exercises post-surgery can reduce pulmonary complication. Breathing games were developed for the basic method – spirometry [5], or using capacitive textile sensor [6].

Therefore we decided to measure ventilation with pressure belts that are cheaper and more accessible than other methods. This measurement is relative but sufficient for training correct breathing and for continuous breath monitoring during the game-based therapy. The game application TRABR (TRAining of BReath) with pressure belts was developed for proper training of breath the division of thoracic and abdominal breathing.

2. METHODS

The measurement is based on monitoring changes in pressure in belts. The pressure cuffs are strapped around the chest and abdomen and pump air into the belt with the hand bulb, and monitor the pressure associated with the expansion and contraction of the chest during breathing. The positions of cuffs are showed in Figure 1 (left), where the upper belt watches thoracic breathing and conversely lower belt watches abdominal breathing. Each belt has a pressure gas sensor which is connected to the strip can monitor respiratory breathing. The sensor comprises a membrane, on one side of which is a vacuum, the other side is loosely associated with the environment. Pressure variations cause flexing of the membrane, which is converted to voltage.

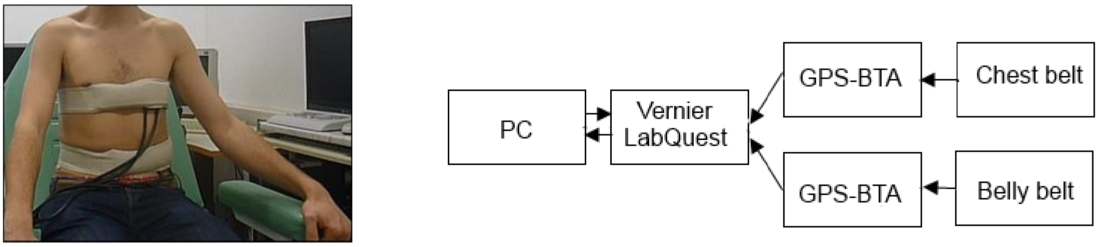

Figure 1: Patients with pressure belts (left); Block schema of the breath belt monitor (right)

Block diagram of the method is shown in Figure 1 (right). We used the data logger from Vernier Company. Vernier LabQuest is an autonomous measuring device that works with any connected sensors. Acquisition card is then being connected to a PC via a cable and the measuring data through the USB port to the computer. Pressure sensors are connected to the data logger. Each pressure belt has a pressure sensor, and for this reason, in order to precisely detect the thoracic and abdominal respiration.

2.1. PROGRAM APPLICATION TRABR

TRABR game is aimed at the isolated training respiration in therapy. The application is designed in C # and the screenshot is shown in Figure 2.

First, belts have to be attached to the patient. Initialization (Figure 2: Part 1) and device calibration follows (Figure 2: Part 2). User settings include the selection level (Figure 2: Part 3), respiratory rate (Figure 2: Part 8), delay abdominal breathing (Figure 2: Part 9) and setting time (Figure 2: Part 4). After setting all the previous operations start the game can by pressing START (Figure 2: Part 5). The program must be switched to tab Wave (Figure 2: Part 6). In this tab, Wave, we can see two graphs, the upper graph for thoracic breathing and lower graph on abdominal breathing. The x-axis is time and y-axis is pressure in belts. After starting the game, two sine waves in both graphs are displayed and the patient must follow them. See red and blue curve between two green clipped sinusoidal curves in graph on Figure 2.

The clipped sine wave simulates an ideal breathing curve. The sine wave guides patient's breathing. The patient trains to stay between the two sine waves. Correct isolated breathing is following: inhale into the chest, inhale into the abdomen exhale from the chest, exhale from the belly. Clipped sine wave for abdominal breathing is phase shifted by delay. Patient (user) can choose the level of play by distances between two clipped sine waves, which correspond to game difficulty. Levels are Easy, Medium easy, Medium, Medium difficult and Difficult. The easiest level corresponds to largest distance. Respiratory rate determined by the number of breaths per minute. The user chooses between Eupnoea (normal rate), tachypnea (increased frequency) and bradypnoea (reduced rate). Next, set the delay abdominal breathing. Furthermore, the user selects the measurement time. The medium level, Eupnoea, medium delay and 60 seconds are set up defaultly. The game is stopped after the expiry of the time limit or after pressing the stop button (Figure 2: Part 7).

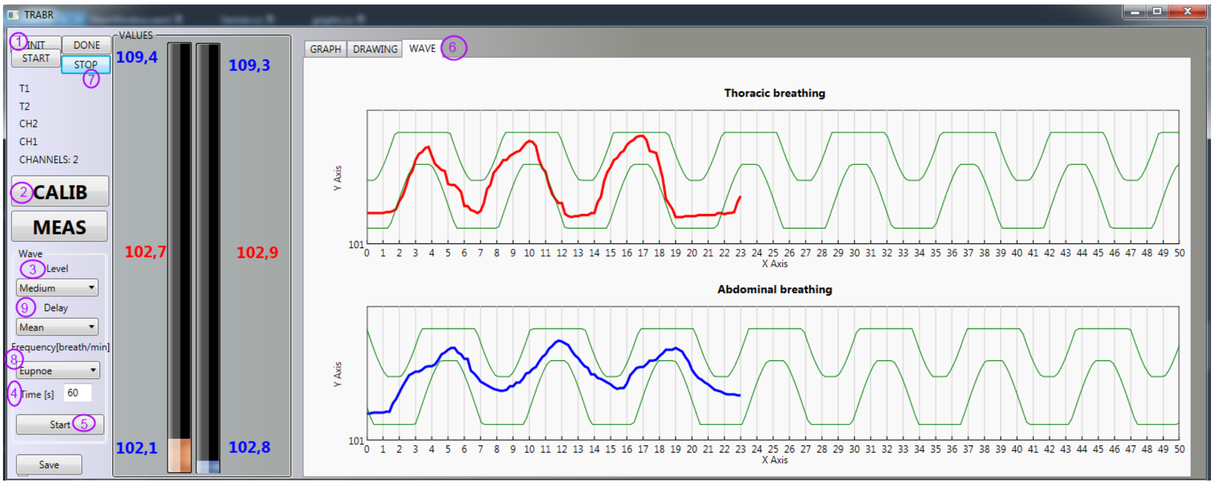

Figure 2: Screenshot from .NET control application - isolated chest and belly breath

2.2. TRAINING SCORE

We used two evaluation training for breath. How many times a patient could not hold breathe in the way, and the average deviation from the path. The training score is used to evaluate training. After completing the game, sums of elements for both respiratory curves are defined according to these formulas:

$$A = \sum_{k=0}^{K} a(k), \tag{1}$$

$$B = \sum_{k=0}^{K} b(k), \tag{2}$$

where A is the relationship of abdominal breathing, B is the relationship of the thoracic breathing. K is the number of samples and k is a current element. The current elements are evaluated according to the following criteria:

$$a(k) = \begin{cases} 0 & for \quad \sin_{lower}(k) \le breath(k) \le \sin_{upper}(k) \\ 1 & for \quad breath(k) > \sin_{upper}(k), breath(k) < \sin_{lower}(k) \end{cases}, \tag{3}$$

$$b(k) = \begin{cases} 0 & for \quad \sin_{lower}(k) \leq breath(k) \leq \sin_{upper}(k) \\ 1 & for \quad breath(k) > \sin_{upper}(k), breath(k) < \sin_{lower}(k) \end{cases}, \tag{4}$$

where a is valid for abdominal breathing and b is valid for thoracic breathing.

The training score is defined as:

$$TS_A = \frac{A}{K} \cdot 100 \ [\%], \tag{5}$$

$$TS_B = \frac{B}{K} \cdot 100 \ [\%], \tag{6}$$

where TS_A is training score of abdominal breathing, TS_B is training score of thoracic breathing. The ideal situation is when the patient stays in the way throughout the measurement, i.e. 0% in each area. The second method of evaluation is the average deviation from the path. We know the ideal path where the patient should move breath. By size deviation from the path of the breath is added again penalty. The sum of these penalties is divided by the sum of the number of displacements (equations 1 and 2). According to the average deviation from the border path is the result divided into categories: excellent, very good, good, satisfactory and unsatisfactory. The patient can judge whether you may choose a harder level or will be more practice. The training scores of both patient breaths are displayed after the game is finished (Figure 3).

This method uses relative measurement and is used to correct breathing habits during therapy exercises. The patient may be tested on different levels of variously long time; and trained for isolated breathing.

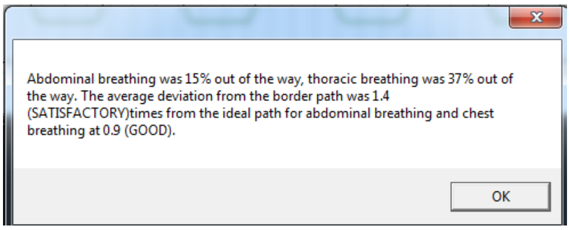

Figure 3: Evaluation of the game

2.3. ANOTHER USE OF THE PROGRAM

The program can be used also as diagnostic tool. Respiratory signals according to the specific measurement protocol are measured for further processing.

Again, calibrate and both breathing signals are plotted in Graph tab. A proposed examination works as follows: a patient sits down on a chair to easier manipulation with the measurement devices and the pressure belts are fixing on his or her body. Next, measurement begins.

In our case, the measurement protocol is proposed: first, the patient breaths normally. Then, a maximum inhalation and exhalation are detected for setting up measurement range. The examination continuous with three sets of measurements consisting of multiple sharp inhalations into abdomen, into chest and finally into both human body parts. The measured data can be saved and next analyzed. The percentage of thoracic and abdominal breath, denoted as PT and PA, where:

$$PT = \frac{\frac{VarT}{MaxT}}{\frac{VarT}{MaxT} + \frac{VarA}{MaxA}} \cdot 100 \, [\%], \tag{7}$$

$$PA = \frac{\frac{VarA}{MaxA}}{\frac{VarA}{MaxA} + \frac{VarT}{MaxT}} \cdot 100 \, [\%], \tag{8}$$

where *T* is the signal from the thoracic breathing, *A* the signal from the abdominal breathing. *Var* is a difference of average maxima and minima responses. Maximum is defined as the average of all local maxima. Similarly, the minimum response is defined as the average of all local minima.

3. CONCLUSION

The proposed method is accompanied with a program for practicing of inhalation into isolated body parts. The training program is conceived as a set of interactive games: a patient selects a game and follows instructions that guide him or her to improve inhalation into isolated parts. When all the desired actions are finished, the program automatically evaluates whether the patient prefers thoracic or abdominal breathing.

TRABR should be used as therapy and also diagnostic tool. For therapy use tab Wave, so patient can practice inhalation into isolated parts. To analyze patient's breathing habits and determine reliable whether he or she is able to inhale into chest or abdomen is diagnostic domain, use tab Graph. TRABR is suitable for home therapy thanks to simple operation and low price.

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