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Training Isolated Respiratory in Rehabilitation

Marketa Kotova, Jana Kolarova, Ludek Zalud, Petr Dobsak

Abstract—A game for training of breath (TRABR) for continuous monitoring of pulmonary ventilation during the patients' therapy focuses especially on monitoring of their ventilation processes. It is necessary to detect, monitor and differentiate abdominal and thoracic breathing during the therapy. It is a fun form of rehabilitation where the patient plays and also practicing isolated breathing. 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, game TRABR (TRAining of BReath).

I. Introduction

BREATHING (pulmonary ventilation) is one of the physiological needs for humans. 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 [1]. Those with Posttraumatic Stress Disorder (PTSD) may think its just part of being alive, except breathing has far reaching implications to produce heightened / exacerbated symptoms for those suffering PTSD. An incorrect breathing habit can contribute to anxiety, panic attacks, depression, muscle tension, fatigue and more [2]. According to Charles Stroebel, breathing can be implicated in 50 - 70 percent of diseases. Dr. Konstantin Buteyko, claims that more than 150 chronic diseases are contributed to, or directly caused, by incorrect breathing [5]. Claims that more than 150 chronic diseases are contributed to, or directly caused, by incorrect breathing. It has been shown by a number of different researchers that shortened breath-holding time correlates with chronic hyperventilation, low CO_2 levels in the lungs and blood, a lowered anaerobic threshold and a low level of bicarbonate buffer stores in the blood. In healthy breathing, breath-holding time after exhalation should be between 30 - 60 seconds [3], [4].

The three basic types of respiration are abdominal, thoracic and subclavian. In abdominal breathing, your belly goes outward on an inhale and draws inward on an exhale. The diaphragm, abdominals and intercostals, the muscles between the ribs, work in tandem to breathe fully. Breath is the very thing that sustains the body; without oxygen our system begins to shut down. Full expansion and contraction of the diaphragm floods fresh oxygenated blood throughout the body and leads to mental centeredness. Allowing the breath to flow, even in chaotic situations, leads to a calmer, steadier state of mind that trickles to a tense-free body system. Conversely, the lack of realization of this type of breathing can result in a greater tendency to constipation, indigestion and hemorrhoids. [8], [9]

During thoracic breathing, lower layers of the lungs, which are most valuable in oxygen transport, get much less, if any, fresh air (less oxygen supply). This causes reduced oxygenation of arterial blood in the lungs and can lead to so called "ventilation-perfusion" mismatch (as in COPD or emphysema) [7], [9]. Dr. Shields, in his study, "Lymph, lymph glands, and homeostasis" reported that diaphragmatic breathing stimulates the cleansing work of the lymph system by creating a negative pressure pulling the lymph through the lymph system. This increases the rate of elimination of toxins from visceral organs by about 15 times [6].

Subclavian breathing through the involvement of muscles and movement mechanics differ significantly from breath chest. The subclavian breathing involved and oblique muscles of the neck. Breathing untrained person can engage these muscles only in case of acute respiratory distress (asthma, choking, etc.) [10]. For these reasons, the methods focus only on monitoring thoracic and abdominal breathing.

The spirometry is a basic method examination of ventilation. Its disadvantage is the use of mouthpiece or mask also, spirometry is unable to distinguish abdominal and thoracic breathing. The examination is also dependent on patient compliance. Further, examination depends on the patient's age. Diagnosis of a disease is often difficult in early childhood – young children are not able to cooperate [11], [12]. For these reasons, other methods have been developed. These methods are completely contactless or operate without any problem with mouthpieces. These methods are based on detection of lung volumes or a shift in the chest or abdomen by various detectors [13], [15], [16], [17].

Changing your breathing type when awake takes time, but you can get this happening within minutes. It will take you months of constant conscious assessment to catch yourself breathing incorrectly, correct yourself, and continue, yet with practice it will become instinctual [2]. Using our method, it is easy to verify the accuracy of respiration in a fun way.

The advantage of this system can be a self-managed, at-home therapy system; reducing fatigue for physical therapists, and the time required for therapist-patient sessions. It is known that

M. Kotova and J. Kolarova are with Department of Biomedical Engineering, Brno University of Technology, Brno, Czech Republic (e-mail: xkotov01@stud.feec.vutbr.cz; kolarova@feec.vutbr.cz).
L. Zalud is with Department of Control and Instrumentation, Brno University of Technology, Brno, Czech Republic, e-mail: zalud@feec.vutbr.cz
P. Dobsak is with the Department of Sports Medicine and Rehabilitation, St. Ann's University Hospital Brno, Brno, Czech Republic (e-mail: petr.dobsak@fnusa.cz).
M. Kotova, J. Kolarova, L. Zalud and P. Dobsak are with the International Clinical Research Center, Center of Biomedical Engineering, St. Ann's University Hospital Brno, Brno, Czech Republic.

Fig. 1. A subject with pressure belts

games can promote patients' concentration and dedication, as well as shift attentions of patients' uncomfortableness during rehabilitation.
Our method measures ventilation with pressure belts becouse these are cheaper and more accessible (more affordable) than other methods (respirarory inductive plethysmography, impedance pletysmography or optoelectronic plethysmography [13], [18], [15]). This measurement is relative and sufficient for training of correct breathing and for continuous breath monitoring during the game-based therapy [14]. The game TRABR (TRAining of BReath) with pressure belts was developed for proper training of breath the division of thoracic and abdominal breathing.

II. Method

The measurement is based on monitoring of changis of a pressure in the belts. The pressure cuffs are strapped around the chest and abdomen and the air is pumped into the belt with the hand bulb. The pressure assocciated with the expansion and contraction of the chest during breathing is monitored/measured. The positions of cuffs are showed in Fig. 1, where the upper belt watches thoracic breathing and conversely lower belt measures abdominal breathing. Each belt has a pressure gas sensor which is connected to the strip that can measure respiratory breathing. The sensor comprises of 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.
Block diagram of the measuring chain is shown in Fig. 2. We used the data logger by Vernier Company. Vernier LabQuest is an stand-alone measuring device that works with any connected sensors. Acquisition card is 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, in order to precisely detect the thoracic and abdominal respiration.

III. Program application TRABR

First, measuring sensors are attached to the pacient's body during an examination. After calibrates the device. Therapy may begin after calibration.
The measuring strips are attached to the subject's body

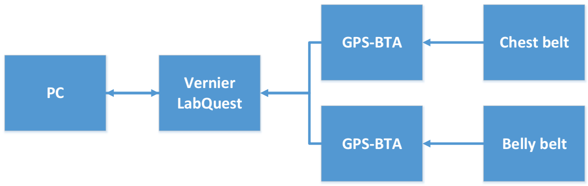

Fig. 2. Block schema of the breath belt monitor

through the breast (thoracic breathing monitor) and the level of the navel (belly breathing monitor) (Fig. 1). Air pockets pressure belts must be placed on the breasts and navel, not on the side or back of the subject body.
Calibration is carried out before each selected game. The user sets their breaths reference pressure range corresponding to the maximum tidal volume (maximum inhalation and maximum exhalation).
Fig. 3 shows user settings include the selection level (red), respiratory rate (yellow), delay of abdominal breathing (green) and time setting (blue). The game has five levels. The easiest level corresponds to the largest distance between the borders of the way. A respiratory rate is determined by the number of breaths per minute. The user chooses between *Eupnoea* (normal rate), *Tachypnea* (increased frequency) and *Bradypnoea* (reduced rate). Setting the delay abdominal breathing from the chest breathing and furthermore, the user selects the measurement time. The game is stopped after the expiration of the time limit or after pressing the stop button
The game begins by pressing the START button after setting all the previous operations. The program displays two graphs, the upper graph for thoracic breathing and lower graph on abdominal breathing. The x-axis corresponds to time and y-axis is pressure in belts. Two clipped sine waves in both graphs are displayed and the subject must follows them.

A. Failure analysis

Failure analysis gives the how many times a subject breathe could not hold in the way. After completion of the game, sums of elements for both respiratory curves are defined according to these formulas:

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

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

$$X(k) = \begin{cases} 0 & \text{if } b_{lowX}(k) \leq r(k) \leq b_{upX}(k), \\ 1 & \text{if } r(k) > b_{upX}(k) \vee r(k) < b_{lowX}(k) \end{cases} \tag{2}$$

The current elements $a(k)$ for abdominal breathing is calculated by (2) where X are the parameters of the path of abdominal breathing. The current elements $b(k)$ for thoracic

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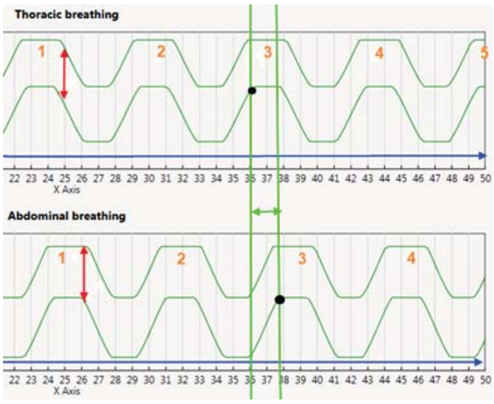

Fig. 3. Adjustable parameters games

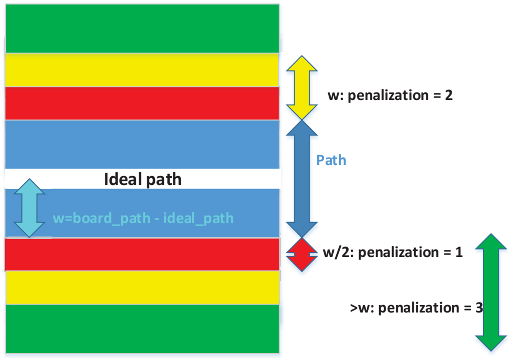

Fig. 4. Game Rating- how the subject went out of the way

breathing is calculated by (2) where X are the parameters of the path of thoracic breathing. The parameter b_{up} is upper board of path and parameter b_{low} is lower board of path. The parameter r is current sample of respiration.
The failure analysis are defined as:

$$FA_A = \frac{A}{K} \cdot 100[\%] \qquad FA_B = \frac{B}{K} \cdot 100[\%] \tag{3}$$

where FA_A is failure analysis of abdominal breathing, FA_B is failure analysis of thoracic breathing. The ideal situation is when the subject stays in the way throughout the measurement, i.e. 0% in each area.

B. *Penalization*

The second method of evaluation is the average deviation from the path where the subject has to hold his breath. Ideal path is the middle path:

$$ideal_X = (b_{upX} + b_{lowX})/2 \tag{4}$$

where b_{up} is upper board of path, b_{low} is lower board of path. Ideal way of thoracic breathing is calculated according to (4), where X are the parameters of the way the chest breathing. Ideal way of abdominal breathing is calculated according to (4), where X are the parameters of the path abdominal breathing.
The penalty in the use of distance border path and ideal path:

$$w_X = b_{upX} - ideal_X \tag{5}$$

Size w for thoracic respiration is calculated by (5) where X are the parameters of the path of thoracic breathing. Size w for abdominal respiration is calculated by (5) where X are the parameters of the path of abdominal breathing.
The sum of these penalties is divided by the sum of the number of displacements (1). Penalties are given as follows:

$$P_X = \begin{cases} 0 & \text{if } b_{lowX} < r(k) < b_{upX}, \\ 1 & \text{if } b_{upX} < r(k) < w_X/2 \vee b_{lowX} > r(k) > w_X/2, \\ 2 & \text{if } w_X/2 < r(k) < w_X \vee w_X/2 > r(k) > w_X, \\ 3 & \text{if } w_X < r(k) \vee w_X > r(k), \end{cases} \tag{6}$$

where $r(k)$ is current sample of respiration. P_A (penalty for abdominal breathing) was calculated by (6) wherein X, the parameters of abdominal breathing. P_B (penalty for thoracic breathing) was calculated by (6) wherein X, the parameters of thoracic breathing. Penalty is shown in Fig. 4.

$$penalization_A = \frac{P_A}{A} \qquad penalization_B = \frac{P_B}{B} \tag{7}$$

where A is number of deflections off the path for abdominal breathing (1) and B is number of deflections off the path for thoracic breathing (1).

IV. Graphical User Interface

Section *Graphical User Interface* displays the main window of game TRABR, description of setting and simplification of the results.
Fig. 5 shows the main window TRABR. Is first performed calibration (Fig. 5: Part 1). The user sets the subject information: name, surname and identity number (Fig. 5: Part 2). Sets the date of examination (Fig. 5: Part 3) and the parameters of the game (Fig. 5: Part 4). After setting all the previous operations start the game can by pressing START (Fig. 2: Part 5). The program must be switched to tab Wave (Fig. 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 subject results to show the user after the game (Fig. 5: Part 7).
Users show the number of times the subject was breathing off the path in percentages and penalties - how much the subject's breath deviate from the path. According to the results achieved are assigned marks for better clarity: excellent, very good, good, satisfactory and unsatisfactory.

- Excellent: Penalization $\leq$ 1,05
- Very Good: 1,05 $<$ Penalization $\leq$ 1,3
- Good: 1,3 $<$ Penalization $\leq$ 1,6
- Satisfactory: 1,6 $<$ Penalization $\leq$ 1,8
- Unsatisfactory: Penalization $>$ 1,8

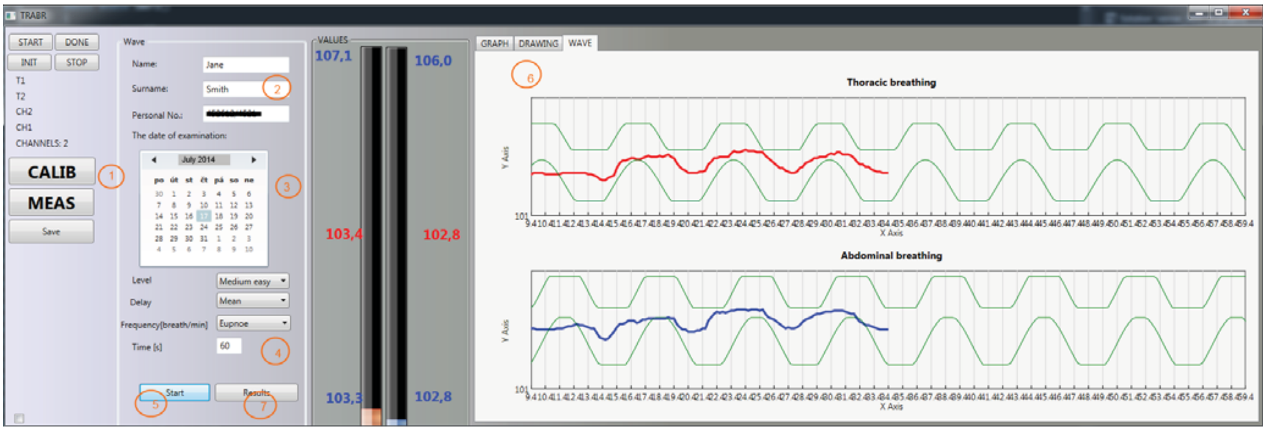

Fig. 5. Screenshot from .NET control application - isolated chest and belly breath

TABLE I
THE ARCHIEVED LEVEL

Subject	After 14 days	After 1 month	The difference of level
1	1	0	1
2	1	0	1
3	0	1	1
4	1	1	2
5	1	2	3
6	0	2	2
7	0	2	2
8	1	2	3
9	2	1	3
10	3	0	3

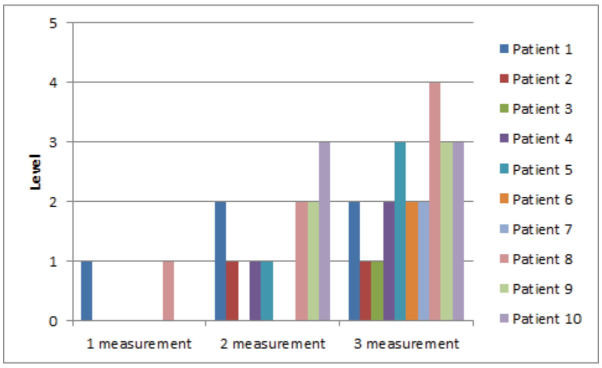

Fig. 6. Results of subjects in one month measurement

V. Results

The experimental results were carried out on a group of 10 subjects (both, males and females) between 20 - 30 years old. The experimental phase took 4 weeks with measurements taken on the first day, after two weeks and at the end of the month. All experiments were measured over the interval of 60 seconds. All experiments started at the easiest level. If results of both measurements (abdominal and thoracic) were above the average, the subjects continued the therapy on the next level. After two weeks, during which subjects worked on their breathing at homes, the experiments started at the first unsuccessful level from the first experiments. The same procedure was repeated for the last measurement at the end of the month.
The next round was secured when the subject received ”stamps”:

- *Excelent* for both breathing
- *Excelent* for first breathing and *Very Good* for second breathing

Tab. I and Fig. 6 show the results. Completion levels after 14 days and after 1 month are entered in the table. The average improvement of 1.0 levels for first 14 days, 1.1 levels fo second 14 days. The overall average improvement of 2.1 levels for the entire period of measurement. The course of individual subjects shows in Fig. 6. The subject 8 has succeeded in a first measurement level, the next level added in the second measurement, the other two levels added in the last measurement. The most difficult level has not been done. From the results it may be concluded that it is possible to train isolated breathing using the method with pressure belts.

VI. 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 subject 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 subject prefers thoracic or abdominal breathing.
TRABR should be used as therapy and also diagnostic tool. TRABR is suitable for home therapy thanks to simple operation and low price.

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