INFLUENCE OF THE INTERVENTION PROGRAM ACCORDING TO PULMONARY REHABILITATION PRINCIPLES ON BREATHING FUNCTIONS OF HEALTHY INDIVIDUALS

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ABSTRACT

Purpose: The aim of the study is to develop and verify an intervention program based on findings of the subject field Pulmonary Rehabilitation and the application of such programme to a daily program of healthy probands over a six-week period. The authors were concerned with determining whether an intervention program, based on a combination of aerobic load and resistance training, might affect the breathing stereotype and breathing functions in healthy individuals.
Methods: Muscle dynamometer MD03 was used to examine the extent of engagement of individual breathing regions. Breathing functions, or more specifically, the forced vital capacity (FVC) and one-second vital capacity (FEV_1), were measured by means of Spirometer Otthon, and the evaluation was conducted using program ThorSoft. The intervention included 6 probands at the age of 21.3 ± 0.8 who exercise regularly. The probands underwent initial and final tests. The data obtained were evaluated and substantial significance was determined using Cohen's d, and the Student's paired t test for dependent selection. Significance value was determined at significance value α = 0.05. Data were processed in programs Microsoft Excel 2016 and Statistica 12.
Results: The tested set of probands showed a substantially significant change of value FVC (Cohen's d = −0.13, i.e. a small effect). This change was also statistically significant. As regards value FEV_1, a substantially significant change incurred (Cohen's d = −0.23, i.e. a small effect). Likewise, this change was statistically significant. The analysis of breathing movements of the observed group of probands revealed improvement especially in the lower thoracic region (abdominal) following the completion of the intervention program. In resting breathing, a substantially significant (Cohen's d = 2.83, a large effect) as well as statistically significant change was effectuated in this region. In the middle thoracic region, a substantially significant change (Cohen's d = 0.01, i.e. a small effect) incurred; however, there was no statistical change. No substantially or statistically significant changes were obtained for the upper thoracic (subclavian) region.
Conclusion: Our results imply that the aforementioned intervention applied in healthy individuals who exercise regularly hasn't had a positive influence on breathing functions. Though there was a small improvement in the breathing stereotype, the optimum engagement of the abdominal breathing region within the breathing wave as described in specialized literature was not accomplished.

Keywords: breathing wave; breathing regions; breathing stereotype; inspiratory pressure; intervention program; pulmonary rehabilitation

Introduction

Pulmonary rehabilitation is a multidisciplinary program of care provided to patients suffering from chronic respiratory disorder, developed individually with the aim of optimizing physical and social performance. Respiratory physiotherapy is a more specialized term related to respiratory rehabilitation techniques. (Zdařilová et al., 2005). Smolíková & Máček (2010) argue that pulmonary rehabilitation is predominantly engaged in a physical activity treatment directed at improving the adaptation to physical load and an increase in performance. Respiratory physiotherapy includes especially a set of methods and techniques of modified breathing. Accordingly, pulmonary rehabilitation should embrace both methods.

In the physical education practice, the importance of correct breathing has recently been acknowledged with an increasing intensity both in the musculoskeletal perspective, i.e. body alignment, and in the perspective of sports performance.

One of the first studies to objectivise thoracic expansion was conducted by Moll & Wright (1972). These authors draw attention to thoracic expansion as a useful indicator of a disease. Using a centimetre sliding tape, they measured thoracic expansion (perimeter) in the total of 262 subjects (standard population at the ages from 15 to 75 years) at the level of xiphosternal line. The authors concluded, *inter alia*, that after an initial increase, thoracic expansion in subjects had shown a gradual but considerable drop (by 50–60%) with increasing age. Thoracic expansion in men was higher by 13–22% than that in women.

Likewise, current research has revealed the substantial role played by breath in both health and sickness (Gosselink, 2004; Courtney, 2009; Chaitow, Bradley, & Gilbert 2014). In their study, Ragnarsdóttir &Kristinsdóttir (2006) set up an objective consisting in the determination of reference data for breathing movements and patters for healthy men and women. Movements of the upper and lower thorax were measured on both sides (right, left sides) at resting breathing and deep breathing by means of a measuring appliance for respiration movement in 100 probands at the ages from 20 to 69 years. The authors discovered that breathing movements were symmetric and changed only insignificantly with increasing age. The average breathing type in men and women was abdominal breathing at resting breathing. As regards deep breathing, abdominal movements were considerably lower in women when compared with men.

Normal breathing movements are described as a combination of abdominal and lower thoracic movements (Chaitow, Bradley, & Gilbert, 2002). Similarly, Yuan, Drost & McIvor (2013) maintain that the normal breathing pattern consists of inspiration and expiration phases, accompanied by a synchronic movement of the thorax and abdomen. Kaminoff (2006) states that normal breathing signifies a synchronized movement of the upper thoracic and lower thoracic regions and the abdomen.

Dysfunctional breathing constitutes a respiration condition characterized by irregular breathing schemes. Dyspnoea or "thirst for air" are the most frequent primary indicators. Dysfunctional breathing is also associated with non-respiration indicators, such as vertigo and palpitation (Vidotto et al., 2019). Paleček et al. (1999) reason that weakness and fatigue are the most usual functional disorders of respiration muscles. Weakness may be defined as a condition where the ability of a relaxed muscle to generate power is decreased. Contrary to fatigue, weakness is not quickly reversible. CliftonSmith (2017) claims that an incorrect breathing pattern of a sportsman at physical activity may cause early dyspnoea or fatigue of lower extremities, which fact does not reflect cardiovascular fitness or any organic pathology. A disorder of the breathing pattern at rest may interfere with a sportsman's physical performance.

The maximum inspiration pressure is a criterion that is used most often when it comes to evaluating the power of inspiration muscles (Sclauser Pessoa et al., 2014). Paleček et al. (1999) argue that the maximum inspiration pressure is defined by the power and coordination of inspiration muscles. In its declaration as to the testing of respiration muscles, American Thoracic Society & European Respiratory Society (2002) claims that the power of inspiration muscles is reflected by the pressure developed in the thorax. In the respiration system, the power of muscles is generally estimated as pressure, and shortening of muscles as a change in the pulmonary volume or a change in structures of the thoracic or abdominal wall.

Koťová et al. (2014) monitored breath by means of pressure sensors. The research team fixed two pressure belts on a proband, the first belt at the level of navel: this belt monitored abdominal breathing; and the other belt was fixed under arms to monitor thoracic breathing. The authors proved that the above measurement method is capable of discerning isolated breathing during the breathing cycle.

As has already been mentioned, breathing mechanics and gas exchange are positively affected by the complex influence of pulmonary rehabilitation. A long-term influence invokes the development of metabolic adaptation to load, whereby motor capabilities of a weakened or sick individual improve. Attention should be drawn especially at large muscles groups of lower extremities. A minimum intensity should be set up for physical load, which should last for a certain period (Troosters et al., 2005; Smolíková & Máček, 2010). It is recommended to carry out physical activities 3 times a week for about 2 hours. A complex program should last from 6 to 12 weeks, whereas the acknowledgement has been made that a longer application will bring an effect of a more permanent nature. Most often, it is recommended that the program should last 8 weeks, after which measurable positive results are accomplished (Smolíková & Máček, 2010). Similarly, Dovalil et al. (2005) argue that in order to influence the intermuscular coordination and hence to improve the effect of the intramuscular coordination, physical exercises should be conducted for 6 to 8 weeks as a minimum. Interval training is a popular form of exercise, when an exercise unit is divided into short one- or two-minute sessions of a higher intensity load (approximately 80–90% of the maximum heart rate); these sessions take turns with recovery sessions of the same duration. Since lactate cannot be accumulated during such load sessions, the necessary ventilation drops. As a second part, the physical exercise program contains resistance exercises, which not only increase the power of flaccid muscles, but these exercises also - especially in the case of old-aged people - may help regenerate oxidative fibres. This phenomenon does not occur in young individuals. Resistance training is carried out on fitness appliances or by using the weight of own body, such that muscles are in motion at all times despite the considerable resistance load. Most exercises engage two large joints and exercises strengthening various muscle groups alternate (Smolíková & Máček, 2010).

With respect to the aforesaid, the question we have asked was whether an intervention program based on aerobic load and complete with resistance training and basic breathing exercises might have a positive influence on the breathing stereotype.

Methods

The objective of the paper was to develop and verify an intervention program based on findings of the discipline of Pulmonary rehabilitation. We formulated certain hypotheses, where we assumed that a breathing stereotype would be discovered in observed probands corresponding to the optimum breathing pattern (Véle, 2012; Šponar, 2003; Kolář et al., 2009). In addition, it was also assumed that in observed probands, certain selected spirometry data, specifically FVC, FEV_1, would improve considerably. Another presumption was that a breathing stereotype of observed probands would improve as a result of an intervention program, on the basis of an examination conducted by means of the muscle dynamometer MD03. The study included 6 healthy probands (four men and two women) at the age of 21.3 ± 0.8 who exercise regularly.

The muscle dynamometer MD03 was used to carry out a non-invasive examination of the breathing stereotype (Malátová et al., 2007, 2008; Malátová, Bahenský, & Mareš, 2017). In analysing breathing movements, we proceed from the concept of three thoracic sectors. One probe was fixed on each sector by means of belts. The spots for placing the probes were selected based on the kinematics of the three thoracic sectors according to Dylevský (2009). The first probe was placed on the lower thoracic sector on the ventral side at the level $L_{4–5}$. The second probe was placed on the middle thoracic sector at the level of the 8^{th} to 9^{th} ribs on the ventral side, and the third probe was fixed on the upper thoracic sector at the level of the 3^{rd} to 4^{th} ribs on the ventral side in the sternum region. The test was performed in the upright standing posture. The vertical posture is a physiological position for breathing (Smolíková & Máček, 2010). The probes enabled us to record the pressure on sensors exerted by the elevation of the individual breathing sectors for one minute at resting breathing. The same measurement procedure was applied also in the case of deep breathing. The probands were instructed to breathe during the examination as they are accustomed to. As many as 600 values were gained in this manner during an examination of one proband. In processing the data, we worked with the average of recorded maximum inspiration and expiration pressures on the individual probes at resting breathing and deep breathing for one minute.

The examination of breathing functions was carried out by means of the appliance Spirometr Otthon, and the tests were evaluated in the program ThorSoft. Both spirometry tests (FVC, FEV_1) were measured in the upright standing posture. The test methodology observed the appliance manual. Before the intervention program was applied, an initial (control) examination was carried out, and the application of the program was followed by a final examination. The intervention program was based on aerobic load, complete with resistance exercises and basic breathing exercises, the aim of which was to gain awareness of the individual breathing sectors and the subsequent interconnection of these sectors in a breathing wave. The intervention was held twice a week in the form of group exercise sessions during a six-week period under professional guidance.

To evaluate the data, we used Cohen's *d* to determine substantive significance, and Student's paired t-test to determine statistical significance for dependent selections. The level of statistical significance was ascertained at the level of significance $\alpha = 0.05$ (Blahuš, 2000). The generally used evaluation of substantial significance is for coefficient $d \geq 0.80$ – large effect, $d = 0.50$ to 0.80 – medium effect, $d = 0.20$ to 0.50 – slight effect (Cohen, 1988). Data were processed using the program Microsoft Excel 2016 and Statistica 12.

Results

During the analysis of breathing movements (the recorded maximum inspiration and expiration pressures on the individual probes) of the observed group of probands, improvement showed after completion of the intervention program, in particular as regards abdominal breathing, both at resting breathing (Cohen's $d = 2.83$, i.e. large effect), and deep breathing, where an increase was recorded (Cohen's $d = 1.09$, i.e. large effect). Changes in this breathing sectors were substantially and statistically significant. Thoracic breathing considered, values changed only minimally at resting breathing (Cohen's $d = 0.01$), this change is not substantially and statistically significant. As regards deep breathing, a change that is substantially (Cohen's $d = -0.79$, medium effect) and statistically significant occurred after the intervention program. For subclavian breathing at rest (Cohen's $d = 0.34$, slight effect) a substantially significant change occurred; however, there was no statistically significant change. In the case of deep subclavian breathing (Cohen's $d = 0.19$) a substantially significant change did not occur, but a statistically significant change did.

The following text presents our results gained by us when we worked only with the recorded maximum inspiration pressures exerted on the individual probes in the given breathing sectors.

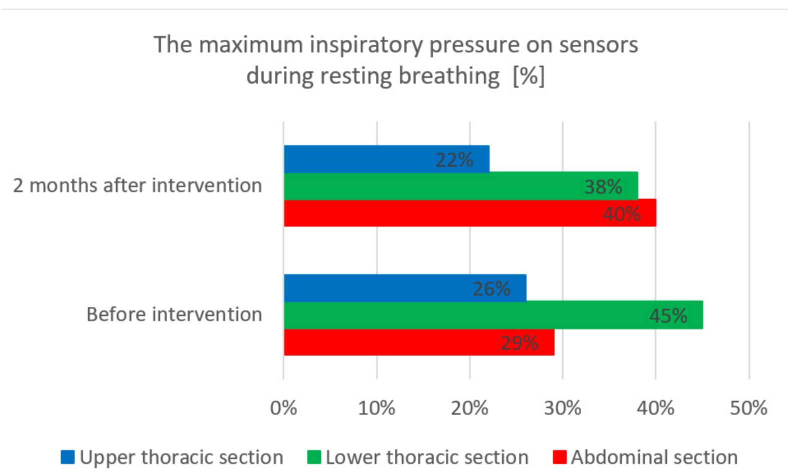

Figure 1 *Engagement of breathing sectors before and after the intervention at resting breathing*

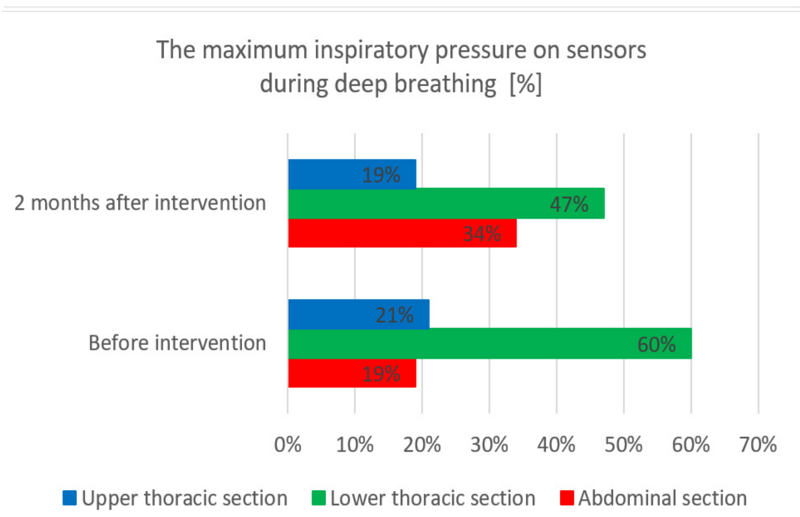

Figure 2 *Engagement of breathing sectors before and after the intervention at deep breathing*

Figures 1 and 2 show that the intervention yielded an improvement in the engagement of the abdominal sector in the framework of the breathing wave both at resting breathing and deep breathing. It may be stated that the intervention led to a better coordination of inspiration muscles.

Next, we present results of the measurement of forced vital capacity (FVC) and forced expiratory volume in one second (FEV_1). The values measured before the intervention were as follows: FVC 5.45 ± 0.9 and FEV_1 4.563 ± 0.691. After the intervention, the values were lower: FVC stood at 5.338 ± 0,843 and FEV_1 was 4.408 ± 0.64. Both values slightly decline, by 2% for FVC and by 3.4% for FEV_1. In the tested set of probands, the change of FVC was not substantially significant (Cohen's $d = -0.13$); nonetheless, the change is statistically significant. As regards the value of FEV_1, the change of FEV_1 was substantially significant (Cohen's $d = -0.23$, slight effect); this change is also statistically significant.

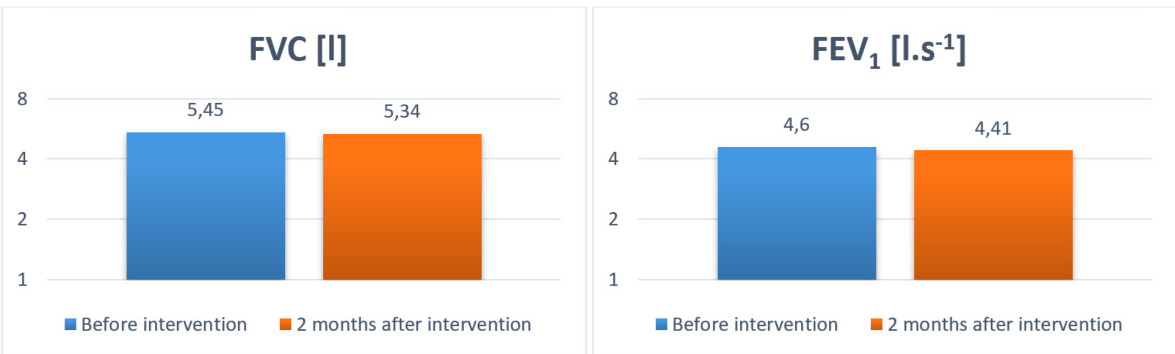

Figure 3 *a) Graphic representation of forced vital capacity (FVC) before and after the intervention, b) Graphic representation of forced expiratory volume in one second before and after the intervention (FEV_1).*

Discussion

All breathing sectors should be engaged during the correct breathing pattern (Véle, 2012; Kolář et al., 2009). As Figures 1 and 2 reveal, the probands activated the given breathing sectors both before and after the intervention. Another issue is the proportion in which these sectors should be engaged. It is claimed in specialized literature (Kolář et al., 2009; Dylevský, 2009; Kocjan et al., 2017; Bordoni & Zanier, 3013; Chaitow, Bradley, & Gilbert, 2014) that the diaphragm alone is responsible for 60% to 70% of the overall efficacy of breathing. Kolář et al. (2009) states that the activity of diaphragm as such is adequate to ventilate two thirds of the lung vital capacity. As is common knowledge, the diaphragm decreases actively in inspiration, whereby the abdomen arches slightly and the lower ribs begin to open at the moment when the downward movement of diaphragm stops by abdominal organs through the increasing intraabdominal pressure and the concurrent activity of *m. transversus abdominis* and other abdominal muscles, which slightly curb the passive arching of the abdominal wall. Afterwards, the abdomen arches only slightly, pressure in the lungs decreases to enable the air to flow into the lungs, the intraabdominal pressure continues to increase and is maintained by the isometric activity of muscles of the abdominal wall and the pelvic diaphragm. In this phase, intercostal muscles activate, the diaphragm alone helps raise the lower ribs, hereby extending the thorax.

In the last phase of inspiration, abdominal muscles together with the diaphragm and muscles of the pelvic diaphragm and pelvic girdle stabilize the spine. At the same time, the upper ribs activate and respiration continues upwards as a breathing wave (Véle, 2012). Similarly, Kolář et al. (2009) argue that the content of the abdominal cavity is primarily incompressible, hence in inspiration, organs of the abdominal cavity move caudally and the abdominal wall moves in the external direction. Lower ribs and sternum move cranially. The cranial movement is carried through the sternum to upper ribs, which are also elevated by the activity of auxiliary respiration muscles, whereby the upper part of rib cage is expanded mainly in the anteroposterior direction. Based on the aforesaid, it may be stated that the abdominal sector is the location of where the largest activation takes place. This assertion corresponds to the ratio presented by Šponar (2003), i.e. as regards a breathing wave, the abdominal breathing, costal breathing and subclavian breathing form 60%, 30% and 10%, respectively, of the total efficacy of breathing. In their study, Koťová et al. (2014) concluded that the ratio between the thoracic and abdominal breathing is 49% : 51% in favour of the abdominal breathing. The above ratios were approached by our group neither before nor after the intervention. Individuals who regularly practise sports activities should activate correctly all of the three breathing sectors during a breathing wave. However, this presupposition proved incorrect for the group of probands observed by us. Accordingly, hypothesis 1 was not confirmed. The point to be acknowledged is that a disorder of the breathing stereotype will generally influence the whole body (Chaitow, Bradley, & Gilbert, 2014). The above implies that correct breathing should be given more emphasis in education, especially as regards physical activities of children (Sedlářová et al., 2008). The current unnatural way of life that puts restrictions on natural physical activities, occupational sedentary behaviour and passive ways of spending leisure time all contribute to the fact that contemporary society is unable to breathe correctly (Haichová & Yesudian, 2014). McKeown (2013) is another researcher to claim that the more the society grows richer, the more our lifestyle changes, affecting the way we breathe. Last but not least, Barknowitzová (2004) emphasizes the considerable influence of the today's lifestyle that influences the body alignment and is reflected in the quality of breathing.

The intervention program was based on aerobic training, complete with resistance and basic breathing exercises. The intervention was introduced on account of the fact that this type of training is used not only for the ill but also in sportsmen's training (Smolíková & Máček, 2010). After the intervention, the engagement of the abdominal sector improved in the framework of a breathing wave, for resting breathing and deep breathing to 40% and 34%, respectively, which confirms hypothesis 3. We also observed the manner in which the intervention would affect pulmonary functions, specifically values of FVC and FEV_1. Gosselink et al. (2000) claims that FVC is connected with the power of expiration muscles. In their study, Han & Kim (2018) examined effects of a breathing technique in combination with dynamic exercises of upper extremities on pulmonary functions in healthy men at the age of 20.

The experiment was conducted three times a week for a four-week period. The above authors concluded that the intervention did improve pulmonary functions. However, after the six-week intervention held twice a week, no improvement was seen in our study, which observed healthy individuals who exercise regularly. Contrariwise, the values of FVC and FEV_1 slightly worsened, a fact which might have been caused by the then health condition or inaccurate measurement.

Conclusion

For the observed individuals, our study proved a larger engagement of the middle and upper breathing sectors in comparison with the lower (abdominal) breathing sector both at rest breathing and deep breathing before the intervention and after the application of the intervention. The six-week intervention resulted in improvement of the engagement of the lower (abdominal) breathing sector, at resting breathing from 29% to 40%, and at deep breathing from 19% to 34%. The intervention had a positive influence on the breathing stereotype in the observed group of probands.

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