Title: Breathing pattern of restful and deep breathing

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Purpose: Respiration is a central aspect of our entire being. We know that every activity of the body is closely connected with breathing and the quality of breathing functions is decisive for our health. Current way of life with sedentary occupation and passive leisure result in the fact that today's civilization cannot breathe correctly (Haichová & Yesudian, 2014). The aim of this work was to investigate the course of breathing waves during restful and deep breathing in healthy individuals aged 19–25 who regularly engage in some sort of sports activity.

Methods: To test breathing stereotype in 163 research participants, we used a muscle dynamometer to monitor the dynamics of breathing activity. During analysis of the respiratory movements was based on the concept of three sectors of the chest. In the lower chest sector, the first muscular dynamometer probe was located. The second probe was placed in the middle chest sector and the third probe was placed in the upper chest sector. The breathing dynamometry test was performed in the upright position. With the probes we recorded individual segment movements for one minute during restful breathing and for one minute during deep breathing. In this way, 600 values were recorded for each person from one sensor during breathing at rest. The same number of values was also acquired in deep breathing. The time series thus obtained were then smoothed by the robust locally weighted regression method. Separate ranges and minima (local extrema) were subsequently identified in the evened series. From the values thus obtained, the average of the maximum and minimum for each individual was determined, depending on the location of the sensor and the type of breathing. From these values, the "average difference" for each sensor location and respiration type was determined for each individual. To test normality, the Shapiro-Wilk's normality test was used for each variable. Results are interpreted with 95% confidence. Due to the rejection of the zero hypothesis on data normality, Wilcoxon's pairing tests were used for individual variables in case of verifying the hypothesis of median compliance (or compliance of distribution functions). Numerical results were obtained through MS Excel and R 3.3.0 software.

Results: The values for restful breathing were statistically significantly lower on all sensors than those for deep breathing. During comparison of the percentage involvement of individual chest sectors the activity of breathing waves predominates in the middle and upper chest sections over the activity of the lower chest section. During deep breathing the activity is reduced by nearly 10%.

Conclusion: On the basis of the results it can be concluded that the test individuals suffer from respiratory stereotype disorder.

Key words: breathing waves, breathing sectors, diaphragm, breathing pattern disorders.

Introduction

Breathing is a central aspect of our entire being and one of the most important life functions. Breathing exercises are historically linked to the emergence and the development of physical education schools, philosophical trends or various cultures, but we also find them in connection with medical sciences (Štumbauer, Tlustý, & Malátová, 2015). Since the turn of the century, western medicine has taken note of the important role of breathing in our health (Clifton-Smith & Rowley, 2011). Recently, research has revealed the vital role of breathing in our health as well as in our diseases (Gosselink, 2004; Courtney, 2009; Chaitow, Bradley, & Gilbert, 2014). The concept of dysfunctional breathing or breathing pattern disorders (BPD) has been defined to describe the incorrect forms of breathing stereotypes causing various symptoms (Clifton-Smith & Rowley, 2011). At present, there is an increasing interest in the impact of respiratory dysfunctions on common health problems such as asthma, chronic back pain and headaches, postural stability, cardiovascular diseases, anxiety and depression. Therefore, breathing therapies are increasingly used as a component of the healing methods of the aforementioned health problems (Courtney, 2009). Holistic manual therapy has long recognized dysfunctional breathing as a common disorder, which, if untreated, can have a major effect on the function and structure of the body. It is also noted that although breathing stereotype disorders are common, they are often overlooked and, if not detected and treated, lead to unnecessary complications in the medical condition (Courtney, 2009; Chaitow, Bradley, & Gilbert, 2014).

Breathing movements are accompanied by three different processes. The first one is the mechanical process – it is the mechanics of breathing movements. The second one is the physiological process involving gas exchange and central nervous system irritability changes. The last process that occurs during breathing movements is the controlling process. It is the management of breathing and postural movements with the involvement of the nervous system, including the effect on the psyche, muscles and internal organs (Véle, 2012; Dixhroorn, 1994). Breathing movements are rhythmically repeated in two phases: inspiration (inhalation) and expiration (exhalation). Exhalation has an inhibitory effect on the muscular activity of the postural-locomotive system and can be increased by holding the breath before inspiration. On the contrary, inspiration has an excitatory effect and can also be increased by holding the breath before expiration. Transient short periods between the inspiration and expiration are called preinspirum and preexspirum (Véle, 2006; Smolíková & Máček, 2010).

Both the rib cage and the abdomen are activated with proper breathing. In the ideal situation when inhaling (due to the decrease of the diaphragm position that exerts pressure on the abdominal cavity), the abdomen is slightly expanded (especially the upper parts), then the chest cage opens to the sides and the chest begins to slightly open on the front at the top – we are talking about the respiratory wave. The respiratory wave gradually passes through all three breathing sectors of the chest, the abdomen (from the diaphragm to the pelvic floor), the lower chest (from the diaphragm to the fifth thoracic vertebra), the upper chest (subclavicular, from the fifth thoracic vertebra to the cervical spine) (Kolář et al., 2009). The abdominal sector is responsible for 60% of the total breathing efficiency, the thoracic sector is responsible for 30% of the total breathing efficiency and the subclavicular sector for 10% (Šponar, 2003; Koťová et al., 2014). The percentages given apply to most activities during the day. These ratios change significantly in various types of exercises or some (pathological) changes in the organism, (Šponar, 2003). Similarly, Kaminoff (2006) states that normal breathing involves synchronized movement of the upper chest, lower chest and abdomen. In addition, normal breathing requires adequate diaphragm engagement (Pryor & Prasad, 2002). According to Kolář et al. (2009), the diaphragm itself is able to provide 75% of the intrathoracic space change when breathing is quiet and is sufficient for the ventilation of 2/3 of vital lung capacity. Dylevský (2009) states that the diaphragm itself will provide 60% of the volume of inhaled air. Its share in breathing is the reason why it is considered the most important muscle right after the heart.

Abnormal breathing involves breathing in the upper chest, with a visible increase in upper chest mobility when compared with the lower chest (Chaitow, Bradley, & Gilbert, 2002). Breathing stereotype disorders are defined as inappropriate breathing that is so persistent that it causes changes in the organism without apparent organic cause (Vickery, 2008). Breathing stereotype disorders are present in various individuals with a musculoskeletal disorder (Chaitow, 2004; Kapreli et al., 2009; Perri & Halford, 2004; Roussel, Nijs, & Truijen, 2007; Smith, Russell, & Hodges, 2006) and can be a risk factor for the development of the dysfunction or may be the result of the dysfunction itself. In individuals with discomfort and aches of musculoskeletal origin, we should always assess also the possible breathing pattern disorder (Bradley & Esformes, 2014).

Various methods such as palpation examination of breathing, whole body plethysmography, chest X-ray scan, spirometry, or various devices recording the change of the lift of individual segments of the trunk can be used to assess the breathing stereotype (Cahalin, 2004; Kandus & Satinská, 2001; Lewit, 2003). Involvement of the individual muscular segments is possible, e.g. through a 3-dimensional system (Kaneko & Horie, 2012). Burgos-Vargas et al. (1993) measured the circumference of the chest expansion using a measuring tape on the fourth intervertebral space (arms in the elevated position). A study by Bockenhauer et al. (2007) has confirmed that measurement using a measuring tape is objective for the examination of chest movements in the middle and upper thoracic sector. Véle (1997) states that the volume of breathing capacity is evaluated using spirometry or by measuring the diameter of the chest between the peak inspiration and the expiration in the lower or middle respiratory segments.

The aim of this study was to investigate the respiratory wave pattern, activation of individual thoracic sectors, using a muscle dynamometer during resting and deep breathing. In 2007, Malátová et al. confirmed that muscle dynamometer is able to objectively evaluate the condition of the muscles in the deep stabilisation spinal system (DSSS). As the diaphragm, as the main respiratory muscle, is a part of DSSS, muscle dynamometer was used for the investigation of respiratory movements. This device can detect the activation of respiratory muscles. Thus, the magnitude of the force and its dynamics can be evaluated. There are no previous studies investigating respiratory movements using this method.

Methods

The study included 163 healthy students of the Pedagogical Faculty of the University of South Bohemia in the programme of Physical Education and Sports (TVS) at the age of 19–25. We assumed that those students who regularly do sports and are familiar with the theory from physical education and sports, and principles of healthy movement, would be able to correctly activate all three breathing sectors during the respiratory wave. A research question was asked as to whether TVS students would activate individual breathing sectors at a given percentage representation in relation to the overall breathing efficiency both during breathing at rest and deep breathing. Where the abdominal breathing is responsible for 60% of the total breathing efficiency, the thoracic sector is responsible for 30% of the total breathing efficiency and the subclavicular sector for 10% (Šponar, 2003; Koťová et al., 2014). Furthermore, we assume that the acquired results during the measurement at rest will be lower than the values during deep breathing.

We used a muscular dynamometer to examine the breathing stereotype MD03 (Malátová, Rokytová, & Štumbauer, 2013). The probe locations were selected based on the kinematics of the mentioned thoracic sectors (Dylevský, 2009; Malátová & Bahenský, 2016). Using bands, one probe was fixed in each sector. The first muscular dynamometer probe was located in the lower thoracic sector on the ventral side at the L4-5 level. A second probe was placed in the middle thoracic sector on the ventral side at the level of the 8^{th} to 9^{th} ribs and a third probe was placed in the upper thoracic sector on the ventral side in the area of sternum at the level of the 3rd to 4th ribs (Dylevský, 2009). The breathing dynamometry test was performed in an upright position. The vertical position is physiological for breathing (Smolíková & Máček, 2010). Using the probes, we recorded the lift of individual segments for one minute during breathing at rest and during deep breathing for one minute. The same measurement procedure was used for deep breathing. Subjects were instructed to breathe as usual both during the breathing at rest and deep breathing. This provided 1800 values during breathing at rest for each person. The same number of values was also acquired in deep breathing. The obtained time series were then smoothed using robust locally weighted regression method. Separate ranges and minima (local extrema) were subsequently identified in the even rows. The acquired values were used to determine the average of the maximum and minimum for the individual subject depending on the location of the sensor and the type of breathing. The "average difference" for each sensor location and breathing type was determined for each subject from these values. Shapir-Wilk's normality test was used for each variable to test normality. Results are interpreted with 95% confidence. Due to the rejection of the zero hypothesis on data normality, Wilcoxon's pair tests were used for the individual variables for verifying the hypothesis of median equality (or compliance of distribution functions). Numerical results were obtained through MS Excel and R 3.3.0 software.

Results

Table 1. Percentage of involvement of individual thoracic sectors during breathing at rest.

n=163	Location of the sensor		
	lower thoracic sector	middle thoracic sector	upper thoracic sector
Average difference	0.2965364	0.3486856	0.3764308
Relatively in%	29.02516	34.12956	36.84528

Table 2. Percentage of involvement of individual thoracic sectors during deep breathing.

n=163	Location of the sensor		
	lower thoracic sector	middle thoracic sector	upper thoracic sector
Average difference	0.5477625	1.3253391	0.9909931
Relatively in%	19.12515	46.27428	34.60057

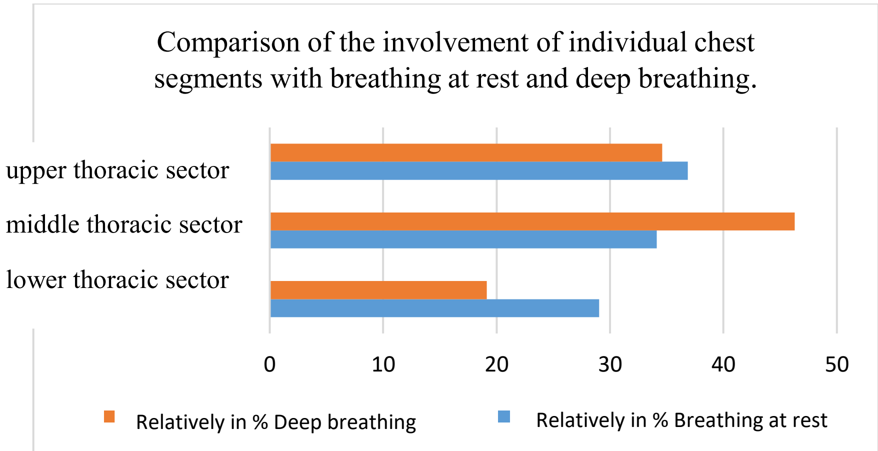

Figure 1. Comparison of the involvement of individual chest segments with breathing at rest and deep breathing.

When comparing the percent involvement of the individual chest sectors in the respiratory wave, the activity of the middle and upper chest sections prevails above the lower chest section. 10% activity limitation occurs during deep breathing in the lower chest sector.

The following table shows the results of normality tests for individual variables – i.e. The location of the sensor (lower, middle and upper thoracic sector) and the types of breathing (resting, deep):

Table 3. Results of normality tests for individual variables.

Breathing type	Location of the sensor	W	p-value
Breathing at rest	lower thoracic sector	0.71138	$< 2.2.10^{-16}$
Breathing at rest	middle thoracic sector	4.836	$4.836.10^{-12}$
Breathing at rest	upper thoracic sector	$7.075.10^{-9}$	$7.075.10^{-9}$
Deep breathing	lower thoracic sector	0.5864	$< 2.2.10^{-16}$
Deep breathing	middle thoracic sector	0.81749	$5.395.10^{-13}$
Deep breathing	upper thoracic sector	0.88062	$3.788.10^{-10}$

Based on the acquired significance levels (p-value) in the above table, we can say that we can reject the zero hypothesis with more than 95% reliability. In other words, not a single selection comes from normal distribution. Due to this fact, it is necessary to use the nonparametric Wilcoxon pair test for subsequent testing. We assumed that the average value in the considered area would be the same as in deep breathing. The zero hypothesis can be rejected with more than 99% reliability based on the measured data and the performed test. In other words, values during breathing at rest are statistically significantly lower than in deep breathing, both in the lower thoracic sector and in the areas of moderate thoracic breathing, as well as in the upper thoracic sector.

Discussion

Based on the results, the research cohort does not activate the respiratory sectors at a given percentage. In the examined group of subjects, thoracic respiration prevails, i.e. the involvement of thoracic sectors (both lower and upper chest) above abdominal breathing, both in breathing at rest and deep breathing. The first assumption that TVS students will generate a respiratory wave with corresponding involvement of the respiratory sectors has not been confirmed. We believe that this may be caused by the dysfunction of DSSS related to body posture. Western European civilization uses the typical pattern of posture that originates in the military – legs hyperextended, weight load on the heels, the chest pushed forward, the stomach pulled in, the shoulders pointing backward, which corresponds to the instruction to stick out the chest and pull in the stomach. If we take this position and watch our breathing, we will find that we are not able to breathe freely (Barknowitz, 2004). Similarly, Kolář et al. (2009) report that we are historically associated with the Sokol view (sports organisation for children and adolescents) of the correct posture, where the shoulder blades are held together, the chest stuck out and the abdomen pulled in. But this is not in line with the ideal posture defined by the central programme. Véle (2012) states that limiting respiratory movements in the lower thoracic sector leads to the destabilisation of the lumbar spine. Consequently, the breathing stereotype changes and chronic hypertonia of the diaphragm and other respiratory muscles develops, with an effect on the whole musculoskeletal system. This is confirmed by the authors Smith, Russell, &

Hodges (2009), who published the conclusions of their longitudinal study (7,499 women) showing that the presence or development of incontinence, respiratory problems and gastrointestinal symptoms are associated with the development of back pain and disturbances in the locomotor system. Bradley and Esformes (2014) report that normal breathing plays a key role in the spinal stabilisation and posture. They have shown that diaphragmatic breathing is closely related to functional movement. The second assumption that the values acquired during breathing at rest would be lower than the values in deep breathing was confirmed. Nevertheless, when comparing the percentage of diaphragmatic respiration (lower thoracic sector) in the respiratory wave, it is evident that there is a 10% activity reduction in deep breathing when compared to respiration at rest. Based on this fact, we agree with the statement of Šponar (2003) that most individuals, who do not deliberately work with breathing, cannot use it optimally. This is related to the surplus tension accompanying our lives.

It follows that we should devote much more time and attention to proper breathing in the education programmes, both in school physical education and in sports activities. Exercises focused on proper breathing and correct posture should start at the pre-school age (Sedlářová et al., 2008).

Conclusion

When comparing the percent involvement of the individual chest sectors in the respiratory wave, the activity of the middle and upper chest sections prevails above the lower chest section. The first assumption has not been confirmed. Respiratory values at rest are statistically significantly lower than in deep breathing, both in the lower and middle thoracic area, as well as in the upper thoracic sector. The second assumption has been confirmed. 10% activity limitation occurs during deep breathing in the lower chest sector when compared to the breathing at rest.

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