BREATHING PATTERN DURING LOAD AND ITS CHANGE DUE TO THE INTERVENTIONAL PROGRAM OF BREATHING EXERCISE

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ABSTRACT

Purpose: Correct breathing pattern in resting breathing is connected to the overall physical health, whereas the breathing pattern affects the performance in endurance sports. The principle of breathing economy consists primarily of the involvement of diaphragm as the main breathing muscle. The paper is engaged in the breathing stereotype in resting breathing and breathing under load. The objective of our paper is to verify whether it is possible to influence breathing stereotype by applying a two-month intervention breathing program.
Methods: The paper examines changes in the resting breathing stereotype and the breathing stereotype during load in adolescent, healthy runners. Twenty participants took part in the intervention. They underwent initial and final tests of the breathing stereotype at rest and in submaximal load. Eleven of them were members of an experimental group and the remaining nine constituted a control group. The experimental group included seven boys at the age of 16.1 ± 1.3, with height 173.2 ± 6.5 cm and weight 56.8 ± 4.6 kg, and four girls at the age of 16.5 ± 0.5, with height 161.7 ± 3.1 cm and weight 54.3 ± 2.3 kg. The breathing stereotype was measured using muscle dynamometer MD03 before and during a indirect calorimetry test conducted on a bicycle ergometer. The data obtained were evaluated in terms of substantive (Cohen's d) and statistical significance ($\alpha = 0.05$).
Results: The breathing intervention resulted in positive changes in the breathing stereotype at rest and under load. At rest, the engagement of the abdominal segment increased by 16.2%, that of the thoracic segment and subclavian segment decreased by 3.6% and 12.6%, respectively, when compared to the initial test. In the submaximal load, the engagement of the abdominal segment increased by 4%, and there was a decrease by 2% for both the thoracic and subclavian segments in comparison to the initial test. The control group showed no significant changes in the engagement of the individual segments of breathing muscles.
Conclusion: Our results has proved that a two-month interventional program of breathing exercises, aimed at activation of the diaphragm and other breathing regions, has a substantial influence on the breathing stereotype both at rest and in the submaximal load.

Keywords: breathing; breathing pattern; breathing exercise; load; diaphragm

Introduction

Breathing is connected not only with gas exchange, but also with the postural function (Hodges & Gandevia, 2000). Breathing movements are divided into three sectors: abdominal, lower thoracic and upper thoracic (Kolář et al., 2009; Véle, 2012). At resting breathing, the lower (abdominal) sector is the first to be activated, followed by the middle sector and then by the upper breathing sector. This gradual activation gives rise to a breathing wave (Dylevský, 2009). In abdominal breathing, the diaphragm is the organ to be most engaged. Thoracic breathing is characterized by predominant engagement of inter-rib muscles. In case of intensive breathing, inter-rib muscles work on expiration as well; in resting breathing, expiration is passive and is taken care of by the elasticity of thorax (Šponar, 2003). In this type of breathing, the body takes in less oxygen in comparison with abdominal breathing (Lysebeth, 1984). In subclavius breathing, inter-rib muscles are engaged, as in thoracic breathing, and in addition, cervical oblique muscles are also active. In clavicular breathing, the less movable shortest ribs are engaged as well: subclavius breathing therefore requires more effort than in case of rib breathing (Šponar, 2003).

The diaphragm is the major breathing muscle on whose activities depends approximately two thirds of gas exchange in lungs (Fleischmann & Linc, 1987). Ganong (1995) and Kolář et al. (2009) argues that in resting breathing, the diaphragm is responsible for up to 75% changes of the thorax volume. Dylevský (2009) maintains that the abdominal sector, which is associated with the activity of the diaphragm, is responsible for 60% of the total efficacy of breathing. In resting breathing, abdominal breathing, thoracic or rib breathing and subclavian breathing would have 60%, 30% and 10%, respectively, within a single breathing wave (Šponar, 2003).

The energy demands of breathing at rest make up approximately 2–5% of the total energy consumption of the body. During intensive muscle work, energy consumption may increase severalfold, especially in persons with limited pliability of lungs or increased resistance of breathing pathways (Slavíková & Švíglerová, 2012). The mechanics of breathing changes during physical activities. Up to a certain intensity (ca. 40 breaths per minute), expiration muscles need not be used, inspiration is active and expiration is passive. Upon reaching a certain level of load intensity, expiration muscles (internal inter-rib muscles and abdominal muscles) must be engaged: this engagement invokes a large consumption of energy. Deep breathing with a lower breathing frequency is more advantageous in economic terms (Havlíčková et al., 2006). Regular endurance physical activities improve the breathing mechanics. The share of diaphragm breathing increases in case of physical load. Trainers and singing teachers lay great emphasis on diaphragm breathing (Bartůňková et al., 2013). Clifton-Smith (2017) states that the athletes who were identified to have a defect of the breathing paters often show an increased rest tone of oblique muscles. If active at rest, these muscles can have an effect of an abdominal corset, which prevents the diaphragm from descending, and creates a dominant pattern of the upper part of thorax.

The examination of maximum inspiration and expiration presses serves for evaluating the strength and functional condition of breathing muscles (De Turk & Cahalin, 2004). To evaluate the breathing stereotype, the following methods may be applied: palpation examination of breathing, whole-body plethysmography, skiagram of thorax, spirometry, or various tools recording changes of the elevation of individual segments of the torso (Cahalin, 2004; Kandus & Satinská, 2001). The engagement of individual segments of muscles can be recorded e.g. by means of a 3-dimensional system (Kaneko & Horie, 2012) or by circumferential parameters of thorax (Bockenhauer et al., 2007; Cahalin, 2004). Another option is to determine the activity of breathing muscles by polyelectromyographic examination (Kandus & Satinská, 2001). The strength of breathing muscles may be examined also by non-invasive examination methods of maximum inspiration and expiration oral pressures (Rochester, 2003) or by means of a muscle dynamometer (Malátová, Bahenský, Kanásová, & Štumbauer 2019; Malátová, Bahenský, & Mareš 2016).

The objective of breathing exercises is to achieve an optimum breathing economy. It is possible to change the breathing stereotype by practising deep breathing, a fact confirmed in their work also by Thomas & McIntosh (1994). When practising, the breathing pattern of participants must be monitored and participants must be notified of inadequacies, if any (Smolíková & Máček, 2010). To achieve a required effect, at least ten breathing exercises must be done, whence the important regular rhythm is created by the body. Static, dynamic and mobilization breathing gymnastics are the most common form used in practice (Kolář et al., 2009). Breathing techniques include isolated breathing, where three different manners of breathing are practised: diaphragm breathing, thoracic breathing and subclavian breathing. The objective of practising diaphragm breathing is in particular to become aware of the diaphragm activity and to learn to control this activity. In turn, the objective of practising thoracic breathing is to increase the elasticity of the rib cage. The objective of practising subclavian breathing is to relax the region of nape and to become aware of the accessibility of upper lung apexes (Lysebeth, 1984). To influence the intermuscular coordination and improve the effect of intermuscular coordination, physical exercises must be done for six to eight weeks as a minimum. Adaptation changes in the form of hypertrophy will show after a longer period, in the range of months and years (Dovalil et al., 2005). The aim of our paper is to verify whether the breathing stereotype during load may be affected by applying a two-month intervention breathing programme.

Methods

This study was implemented at the DPSS of FE of SBU in the Laboratory of Load this Diagnostics. The ethics committee PF JU approved (this) study on October 19, 2018 (002/2018). All subjects have given their informed consent to participate in the research study. The study was attended by 20 middle and long distance runners who have been engaged in endurance training for at least six times a week for one year as a minimum. Eleven of these runners formed an experimental group and the remaining nine became members of a control group. The experimental group consisted of seven boys at the age of 16.1 ± 1.3, with height 173.2 ± 6.5 cm and weight 56.8 ± 4.6 kg, and four girls at the age of 16.5 ± 0.5, with height 161.7 ± 3.1 cm and weight 54.3 ± 2.3 kg. Members of the control group were five boys at the age of 16.3 ± 1.3, with height 172.7 ± 5.5 cm and weight 57.4 ± 4.7 kg, and girls at the age of 16.6 ± 0.5, with height 161.0 ± 4.7 cm and weight 52.9 ± 2.5 kg. The selection was intentional, whereas endurance athletes were chosen because their breathing functions are above-average, a fact implied in the character or specialization of their training. According to the selection criteria, the decisive factors included the adolescent age and at least one-year endurance training.

The paper examined a change of the resting breathing stereotype and the breathing stereotype under load in adolescent, healthy runners. The runners underwent an initial (pre-intervention) and final (after the intervention of breathing exercises) examinations of the breathing stereotype at rest and in the submaximal load (at 4 W . kg^{-1}) during a indirect calorimetry test on a bicycle ergometer. Within the indirect calorimetry test, the initial two-minute warm-up phase at the load of 1 W . kg^{-1} was followed by an escalating test, when the load increases by 0.5 W . kg^{-1} every minute until the test is interrupted by the participant himself/herself. Every participant underwent the same test, with the initial load standing at 1.5 W . kg^{-1}.

The set of breathing exercises was based on yoga and the aim was to activate the diaphragm and to become aware of individual breathing sectors. The intervention programme was held for two months, when the tested group of participants conducted exercises focused on isolated breathing in various positions, practising the breathing wave, full breath and rhythmic breathing. Exercises were carried out in various positions: in a lying position, in a sitting position on heels, in sitting, kneeling and standing positions. Breathing exercises in these positions encourage and invoke changes in the breathing stereotype. Moreover, full breath was practised in accordance with movement in short dynamic sets (Bursová, 2005). The acquisition of breathing exercises was effectuated during the first week of breathing intervention, in the framework of three joint sessions. Breathing during the breathing exercises was done through the nose. At the beginning of the intervention, participants breathed spontaneously, and later proceeded to the extension of the inspiration and expiration phases. Participants carried out exercises at least five times a week for ten minutes as a minimum. Every week, one joint session was held, where the performance of breathing exercises was monitored and corrected. Information on the length of the exercises conducted was recorded by participants; this information was processed on a continuous basis.

Control diagnostics came up after 8 weeks of the application of intervention. The control group was tested at the same time as participants of breathing exercises intervention. Members of the control group performed no breathing exercises. Throughout the intervention period, both groups underwent the identical running training. The breathing stereotype was measured using muscle dynamometer MD 03 before and during the indirect calorimetry test on a bicycle ergometer, for one minute at every stage of the test . The data obtained were assessed in terms of substantive significance by Cohen's d and statistical significance (α = 0.05). The data were processed using the following: Cohen's d to determine substantive significance, Student's paired t-test for depended selections to determine statistical significance. The level of significance was determined at the level of significance $\alpha = 0.05$. Data were processed in programmes Microsoft Excel 2016 and Statistica 12.

Results

Participants carried out breathing exercises for the average of 13.5 ± 3.6 minutes per day during a two-month period. As regards the experimental group, in resting breathing, engagement in the abdominal sector deepened on a substantive significant level, with a large effect (d = 1.20). Initial values 0.55 ± 0.23 N.100 ms^{-1} increased to 0.98 ± 0.44 N.100 ms^{-1}. Engagement in the thoracic sector decreased in substantive significant terms, with a small effect (d = 0.34) from initial values 0.90 ± 0.60 N.100 ms^{-1} to 0.74 ± 0.32 N.100 ms^{-1}, in subclavian sector, the decrease in engagement was insignificant, from initial values 0.52 ± 0.34 N.100 ms^{-1} to 0.49 ± 0.28 N.100 ms^{-1}.

A statistically significant change was recorded for the abdominal sector only. A percentage change is illustrated in figures 1 and 2, where there was a significant increase in the proportion of engagement of the abdominal sector – by 12%. The percentage engagement decreased in the thoracic sector and subclavian sector by 8% and 4%, respectively. Considering the control group, no significant change in the strength of load of probes occurred, the same applies to the engagement of individual sectors. Initial values on the abdominal sector reached 0.61 ± 0.26 N.100 ms^{-1}, and final values were 0.61 ± 0.26 N.100 ms^{-1}. In the thoracic sector, initial values stood at 0.97 ± 0.52 N.100 ms^{-1}, and final values were 0.96 ± 0.52 N.100 ms^{-1}, in the subclavian sector, the initial values were 0.51 ± 0.31 N.100 ms^{-1}, and final values reached 0.52 ± 0.31 N.100 ms^{-1}. No percentage change occured, the engagement of the abdominal sector, thoracic sector and subclavian sector was 32%, 44% and 24%, respectively.

In breathing at the submaximal load, the engagement of all sectors observed increased significantly. Breath deepened considerably and breathing frequency decreased significantly. The change for the abdominal sector has a large effect (d = 1.02), from initial values 1.41 ± 0.63 N.100 ms^{-1} to 2.11 ± 0.74 N.100 ms^{-1}, also the percentage engagement of this sector increased by 2% (see figures 3 and 4). The thoracic sector is characterized by a substantially significant increase in the engagement, with a medium effect (d = 0.72), from initial values 2.83 ± 1.10 N.100 ms^{-1} to 3.59 ± 1.03 N.100 ms^{-1}, the percentage engagement decreased by 2%. The engagement of the subclavian sector increased significantly, with a small effect (d = 0.31), from initial values 1.57 ± 1.05 N.100 ms^{-1} to 1.90 ± 1.12 N.100 ms^{-1}; the percentage share in breathing remained unchanged. A statistically significant change was identified only for the abdominal sector. In the control group, there were no significant changes of the parameters observed. The initial values for the abdominal sectors reached 1.23 ± 0.49 N.100 ms^{-1}, and final values were 1.23 ± 0.48 N.100 ms^{-1}. The initial values for the thoracic sector stood at 2.75 ± 1.17 N.100 ms^{-1}, and final values were 2.76 ± 1.18 N.100 ms^{-1}. For the subclavian sectors, the initial values were 1.43 ± 1.08 N.100 ms^{-1} and final values stood at 1.44 ± 1.08 N.100 ms^{-1}. The percentage share in breathing for all sectors remained unchanged. The engagement of the abdominal sector, thoracic sector and subclavian sector was 25%, 50% and 25%, respectively.

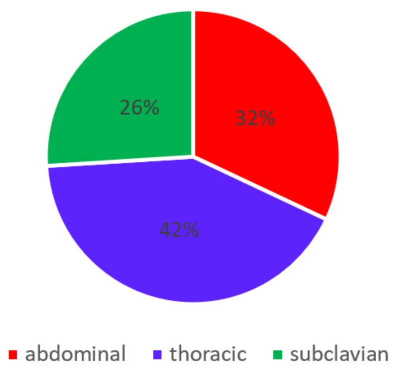

Figure 1 *Engagement of breathing sectors at rest before intervention*

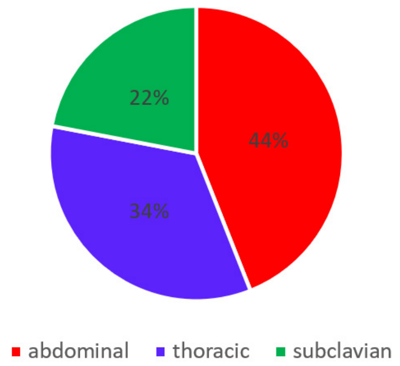

Figure 2 *Engagement of breathing sectors at rest after intervention*

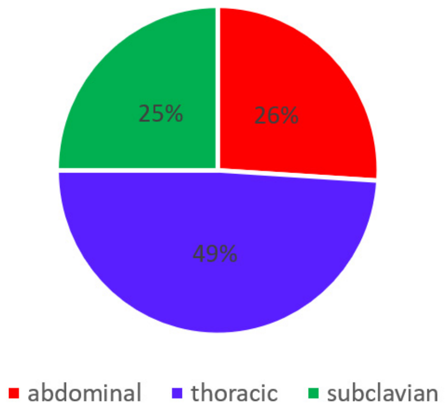

Figure 3 *Engagement of breathing sectors before intervention*

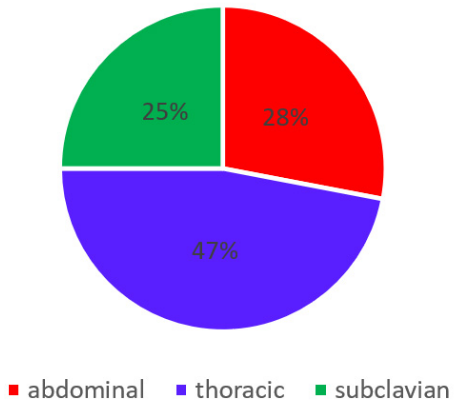

Figure 4 *Engagement of breathing sectors under load under load after intervention*

Discussion

Most studies concerned with the breathing stereotype focus on ill individuals or individuals who have been injured. Certain studies analyse healthy individuals, when it was confirmed that not only static ventilation parameters (Bahenský, Malátová, & Mareš, 2016; Malátová, Bahenský, Kanásová & Štumbauer 2019) but also dynamic ventilation parameters (Bahenský, Malátová, & Bunc, 2019) can be affected in healthy individuals.

Initial tests revealed disorders of the breathing stereotype in all members of the experimental and control groups, whereas the percentage engagement of the abdominal sector reached only 32% at rest in both groups. In the experimental group, the proportion of engagement of the abdominal, thoracic and subclavian sectors changed from 32:42:26% to 44:34:22 % thanks to the intervention; nevertheless, the proportion 60:30:10 % (Šponar, 2003) was not achieved even after the intervention. Physical activities considered, an athlete's ineffective breathing pattern may cause premature dyspnoea, or exhaustion of lower extremities, which does not reflect cardiovascular fitness or any organic pathology. Alternatively, a disorder of the breathing pattern at rest may disrupt an athlete's performance (Clifton-Smith, 2017).

Our intervention programme was developed to cover a period of eight weeks, with emphasis on influencing the breathing pattern. It was confirmed that an eight-week period is a sufficient time for adaptation changes and for improving the breathing economy (McArdle, Katch, & Katch, 1996). The results we have achieved imply that a positive change of the breathing stereotype at rest occured. The percentage engagement of the abdominal breathing segment increased significantly, and the percentage engagement of the thoracic and subclavian percentage sectors decreased in resting breathing. However, despite the improvement in abdominal breathing, the percentage engagement of the abdomen is not utilize sufficiently to achieve the correct breathing stereotype, as described in literature (Kolář et al., 2009; Dylevský, 2000). Instead of the optimum breathing stereotype with a share of abdominal breathing of 60–70%, the participants observed by us reached only the average of 44% engagement in resting breathing.

Under load, the breathing stereotype remained virtually unchanged when compared with results of resting breathing; this result is attributed to latency and the transfer from resting breathing to breathing under load as well as the fact that participants trained the breathing stereotype in resting positions. Even though changes in the engagement of the breathing stereotype are not as significant as those in resting breathing, participants approached the correct percentage threshold of the engagement of individual breathing segment, as determined in literature (Kolář et al., 2009; Bartůňková et al., 2013; Slavíková & Švíglerová, 2012). The change of breathing stereotype under load is significant. To achieve a better breathing stereotype under load, it might be beneficial to undergo an intervention programme with a higher proportion of dynamic exercises, which develop the harmony between breath and movement. The completion of such programme might lead to a faster automation of the corrected breathing stereotype under load.

The study is also limited by the number of the participants involved; it would be advisable to confirm its findings using a larger group of persons. Furthermore, the level of permanency of the effects after the end of intervention of breathing exercises should be determined. The major factors influencing the success rate of the therapy include: regularity and quality of performance of breathing exercises. We consider it suitable to focus on breathing exercises at least for ten minutes five times a week as a minimum. Purposeful breathing exercises may be helpful in improving the breathing pattern and thereby decrease the energy demands of breathing and affect positively the prerequisites for endurance physical activities.

Conclusion

A two-month intervention, with frequency of exercises five times a week, when the length of one unit is 10 min as a minimum, may influence the breathing pattern to a considerable extent and engage the abdominal sector in breathing significantly.

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