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RESEARCH ARTICLE

The Impact of Deep Muscle Training on the Quality of Posture and Breathing

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ABSTRACT. Postural control and breathing are mechanically and neuromuscularly interdependent. Both systems– of spinal stability and respiration– involve the diaphragm, transversus abdominis, intercostal muscles, internal oblique muscles and pelvic floor muscles. The aim of the study was to evaluate the effect of exercises activating deep stabilizer muscles on postural control and quality of breathing movements. Eighteen volunteers (25,7 ± 3,5) were recruited from the general population. All the subjects implemented an exercise program activating deep muscles. Head, pelvic and trunk positions in the sagittal and frontal planes were assessed with the photogrammetric method. Breathing movements were estimated with the respiratory inductive plethysmography. The results indicate that the use of deep muscle training contributed to a significant change in the position of the body in the sagittal plane ($p = 0.008$) and the increase in the amplitude of breathing ($p = 0.001$).

Keywords: motor control, movement, multisegment movement, muscle

The entire motor system comprises many body segments. Their proper alignment with the line of gravity ensures proper posture. Any irregularities in this alignment can result in changes in both closer and further segments or even in the working of particular systems and organs. A number of studies confirm that body posture is conditioned by deep muscle activity (Kibler, Press, & Sciascia, 2006; Panjabi, Abumi, Duranceau, & Oxland, 1989; Tsao & Hodges, 2008). Among others, Hides, Richardson, and Jull (1996) reported that the transversus abdominis, internus obliquus abdominis, and externus obliquus abdominis muscles stabilize the trunk and also play an important role in postural adjustment. In particular, the transversus abdominis, together with the multifidus, plays a major role in stabilizing the lumbar region. The work of Lee, Kim, Kim, Shim, and Lim (2015) and Ainscough-Potts, Morrissey, and Critchley (2006) also confirms the effect of activating deep muscles, including the transversus abdominis, in adjusting and improving body posture.

Many authors believe that correct posture is an important condition for proper respiratory function (Crosibie & Myles, 1985; Pawlicka-Lisowska, Motylewski, Lisowski, Michalak, & Poziomska-Piatkowska, 2013). The tests previously conducted by our team (Szczygieł, Rojek, Golec, Klimek, & Golec, 2010) on healthy participants have shown that even momentary and to a slight extent postural defects have a significant impact on spirometry variables characterizing breathing. Normal breathing, also known as diaphragmatic breathing, involves the synchronized motion of the upper ribcage, lower ribcage, and abdomen. Additionally, it requires adequate use and functionality of the diaphragm muscles. Hodges, Heijnen, and Gandevia (2001) acknowledged that abnormal posture prevents the proper functioning of the diaphragm, resulting in increased activity of the thoracic excursion. Under normal physiological conditions, the diaphragm lowers when air is inhaled and rises during exhalation. Among others, Hodges, Sapsford, and Pengel (2007) and Vostatek, Novak, Rychnovsky, and Rychnovska (2013) believed that the diaphragm has both a postural and a respiratory function. Many reports indicate that both the diaphragm and abdominal muscles, working together, create a hydraulic effect in the abdominal cavity that assists spinal stabilization by stiffening the lumbar spine through increased intra-abdominal pressure (Kolar et al., 2009; Miyamoto, Shimizu & Masuda, 2002). Because of this, deep muscle training is recommended mainly for the prevention and treatment of back pain (Anoop, Suraj, & Dharmendar, 2010; Sumit & Selkar, 2013). Bliss confirms that deep muscle training improves core stability, which is the ability to strengthen the lumbopelvic complex and transfer forces from the upper to the lower limbs of the body while maintaining the spine in a neutral position (Bliss & Teeple, 2005). This muscle group is characterized by early activation independent of the performed movement (i.e., the so-called feedforward or early timing). These muscles work mostly isometrically, with no change in their length (Hadała & Gryckiewicz, 2014). McGill (2010) noted that muscles should generate about 25% of maximum voluntary contraction during the training and closed kinetic chain exercises should be performed to produce an isolated muscle contraction.

Postural control deficits are a common phenomenon, often unnoticed in the clinical evaluation (Ferreira, Duarte, Maldonado, Bersanetti, & Marques, 2011). Among others

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Butowicz, Ebaugh, Noehren, and Silfies (2016) believed that their occurrence is related to the weakening of deep muscles.

We hypothesized that deep muscle exercises have a positive impact on the body posture and, thereby, they can positively influence the breathing movements of the chest.

Our review of the literature, however, indicates a noticeable lack of reports evaluating the impact of deep muscle training on both the posture and the mobility of the chest. Bearing in mind the previously described relations, the purpose of our study was to evaluate the effect of whole program exercises for activating deep stabilizer muscles on the posture and quality of respiratory movements.

Methods

Participants

Twenty-one volunteers between 20 and 30 years old participated in this study. During the implementation of this program, three individuals resigned and, therefore, 18 people completed the program (*M* age 25.7 ± 3.5 years; *M* height 1.69 ± 0.20 cm; *M* weight 64.2 ± 7.3 kg). The participants were recruited from the general nonsmoking population and without any respiratory disorders, chest deformations, pain complaints, or visible postural defects (scoliosis, kyphoscoliosis, barrel, or pectus excavatum). No obesity was observed among the participants (body mass index was below 30 kg/m^2).

Measurements of posture and breathing were made twice: before and after the exercise program.

Posture Evaluation

The posture was assessed with photogrammetrical body positioning using the optoelectronic body explorer (OBE [Department of Photogrammetry and Remote Sensing Informatics]). The OBE is a system positioning selected human body points, which allows for the determination of spatial coordinates of these body points. It belongs to the systems of photogrammetric body evaluation. Such systems provide reliable and reproducible data characterizing the posture (Furlanetto, Sedrez, Candotti, & Loss, 2016; Mikrut & Tokarczyk, 2000).

The measurement was entirely remote. Reflective markers were taped on the points that describe the position of the head, pelvic, and trunk in two dimensions (Table 1) and their positions were captured with an optoelectronic system. Sections created by connection of the indicated points, including the y, x created angles used for further analysis. The y-axis was represented by the vertical alignment line running across the spinous process of the seventh cervical vertebrae (Tokarczyk & Mazur, 2006). In the OBE system, points determined by the photogrammetric measurement represent the transfer of skeleton elements to the body surface and they are signaled by the self-adhesive polystyrene balls of 4–5 mm diameter. The precision of determining the spatial coordinates of the signaled body points is high and amounts to ±2–4 mm. To limit the measurement errors, the balls were fixed by one person. It was a physiotherapeutist, who had been taking measurements with the use of such system for four years.

TABLE 1. Chosen Photogrammetric Points (in the Sagittal and Frontal Planes)

	Sagittal plane
Head posture	The angle between the central part of upper lip, occipital tuberosity, and y-axis
Pelvic posture	The angle between the line between iliac spines and y-axis
Trunk posture	The angle between the line connecting the spinous process of the seventh cervical vertebra and the sacrum and y-axis
	Frontal plane
Head posture	The angle between the left and right eyes and y-axis
Pelvic posture	The angle between the line connecting the superior anterior iliac spines and y-axis
Trunk posture	The angle between the line connecting the spinous process of the seventh cervical vertebra and the sacrum and y-axis

The task of the participants was to keep a casual, habitual standing position with their weight evenly distributed on both feet and looking straight ahead. To evaluate the head posture, the following standards were applied: sagittal plane: 60 ± 1° (values over 60° indicated head in the protraction whereas values below 60° indicated head in the protraction), frontal plane: 90 ± 1° (values over 90° indicated head bend to the right whereas values below 90° indicated head bend to the right).

To evaluate the pelvic the standards were: sagittal plane: 80 ± 1° (values over 80° indicated pelvic in the anterior pelvic tilt whereas values below 80° indicated pelvic in the anterior pelvic tilt), frontal plane: 90 ± 1° (values over 90° indicated pelvic bend to the right whereas values below 90° indicated pelvic bend to the right).

Additionally, the research considered trunk position, also in the sagittal and frontal planes (Table 1). To evaluate the body posture, we applied a standard involving the sagittal and frontal plane: 180 ± 1° (values over 180° indicated body leaning to the right whereas values below 180° indicated body leaning to the left and forward).

Breathing Movement Measurement

Respiratory chest movements were assessed using respiratory inductive plethysmography (Embletta Gold, Mediserv International, Warsaw, Poland). Respiratory inductive plethysmography (RIP) measurements are based on changes to the

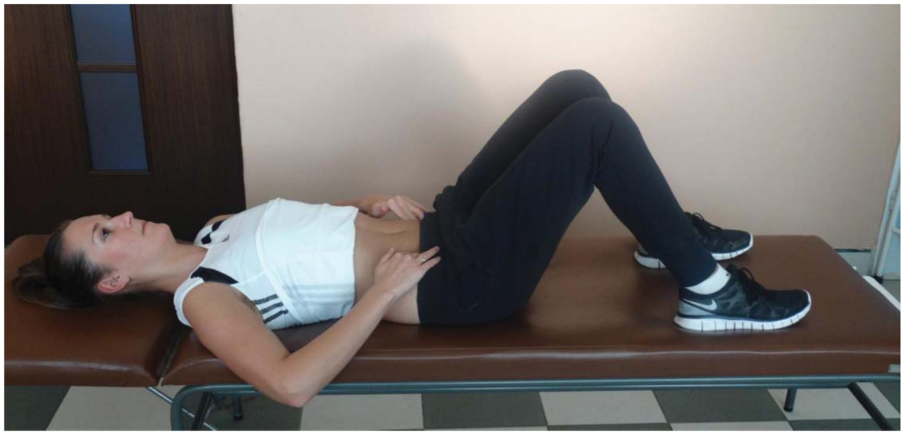

FIGURE 1. Image of the participant performing activating transverse abdominal muscle.

cross-sectional area detected by two inductance belts. Among others Fiamma, Samara, Baconnier, Similowski, and Straus (2007) proved, that the measurement results obtained by this method are accurate. To best utilize the RIP technology, all chest (thoracic excursion) and abdomen (abdominal excursion) respiratory movement measurements were acquired using the XactTrace inductive method. The XactTrace sensors were located on two belts fixed in accordance with the manual; below the arms and level with the navel. The belts were given a slight stretch to fit tightly around the participant and minimize signal distortion, but without limiting chest movement or causing discomfort. After the calibration, the plethysmographic data were recorded for around 3 min. A fragment of the last 1-min record reproduced in RemLogic was selected to assess respiratory movements (http://www.natus.com/index.cfm?page=products_vascular_obstetric&crid=983). The test enabled us to obtain separate charts reflecting the respiratory movements of both the upper and lower chest. The analysis was conducted using individually developed software for analyzing the records of the Embletta Gold system and was possible after prior exporting of the data to an EDF (European Data Format) data recording system. The specially developed software enables finding the amplitude and location of local minima and maxima (peaks and valleys) in the signal, on the basis of which it is possible to conduct further statistical analysis. Statistical analysis allows for determining of the average interpeak Avp value (the amplitude of breath). The amplitude is the value of tension, proportional to the elongation of the belt covering the chest. The measurements were performed in a relaxed standing position.

Exercise Program

All test participants implemented an exercise program activating deep muscles in isolated positions with particular emphasis on transverse abdominal, multifidus, and internal oblique muscles (Figure. 1, 2, 3, 4, 5). Exercises were performed when the participant was lying on their back, bridging, in four-point kneeling positions, and on an unstable surface (Feldwieser, Sheeran, Meana-Esteban, & Sparkes, 2012; Imai et al., 2010; Okubo et al., 2010; Vera-Garcia, Barbado, & Moya, 2014). Each exercise session consisted of three sets of holding a specific posture for 10 s with the trunk straight then resting for 5 s, repeated 10 times. Exercises were performed three times a week for four weeks. The participants declared their consent not to attend other classes or sport activities.

Statistical Analysis

Statistical analysis was performed using Statistica 6.0 software (https://www.statsoft.pl/O-Firmie/O-nas/StatSoft-Polska/). The normality of distribution of test parameters in the groups was presented by the Shapiro-Wilk test whereas the homogeneity in the groups was shown using Levene's test.

To study the relationship between the parameters of photogrammetry and respiratory parameters before the exercises and the difference in parameters before and after the exercises, Pearson's correlation coefficient or Spearman's rank correlation coefficient were used, depending on the normality of the parameter distribution.

To evaluate the statistical significance of differences in the spatial setting of the parameters before and after exercises, Student's *t* test was used where the assumption of normal distribution of the parameters was fulfilled. However, if the previous assumption was not fulfilled, the Wilcoxon test for dependent samples was used. The level of significance less than or equal to .05 was assumed in the analysis.

Results

The descriptive statistics of head, trunk, and pelvic position in sagittal and frontal planes are shown in Table 2. The chest excursion changing is visible on Figures 6 and 7.

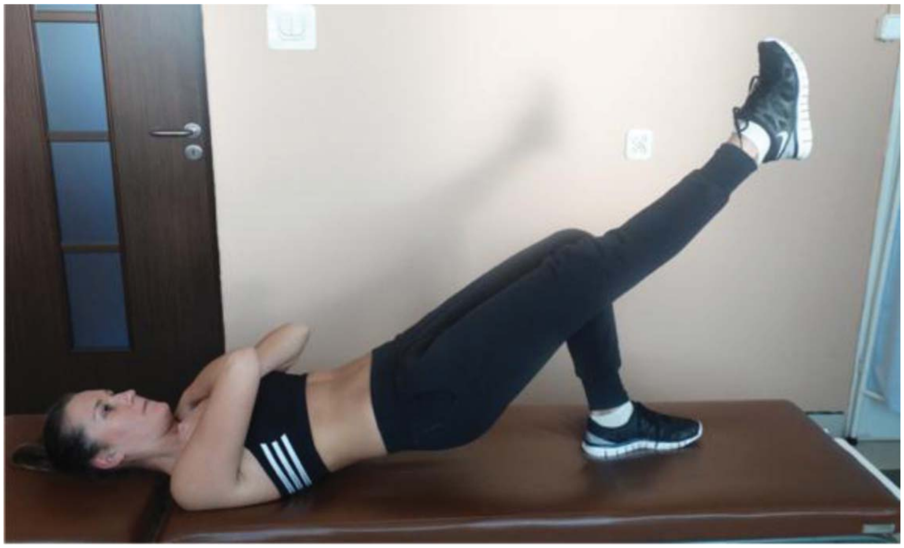

FIGURE 2. Image of the participant performing the back-bridge exercise with elevated leg.

The results obtained from these studies, describing the head, pelvic, and trunk position in the frontal plane, showed distribution compliant with the standard distribution. For that reason, they were participant to further statistical analysis by means of firstly, Student's t test for a single sample, in which the results obtained were compared with the generally applicable standard ($90^\circ \pm 1$ for the head, $90^\circ \pm 1$ for the pelvis, and $180^\circ \pm 1$ for the trunk), and secondly, Student's t test for two independent variables, where, due to the compliance of the results obtained with the standard distribution, variances of the averages were compared, describing the head, pelvic, and trunk leaning. Due to the fact that the results obtained indicated no differences between the right and left-hand side ($p > \alpha$, where $\alpha = .05$), no division into right and left-hand side was taken into account in further analysis.

As the assumptions of normality of variable distribution were fulfilled, Student's t test was used for dependent samples, which allowed for verification of the null hypothesis (H 0), assuming no differences in the spatial position of the head, torso, and pelvis before and after exercise, against the alternative hypothesis (H 1) in which these differences were supposed to occur. If the parameter assumptions in the group after or before exercise were not fulfilled, the Wilcoxon test was used.

FIGURE 3. Image of the participant performing in the four-point kneeling positions exercise with elevated upper limb.

FIGURE 4. Image of the participant performing front-bridge exercise.

The results of the statistical analysis indicate that a significant statistical relationship ($p = .0089$) between trunk setting in the sagittal plane and the amplitude of the respiration in the thoracic excursion (Avp) occurs (Table 3).

Discussion

The aim of this study was to assess the impact of exercise activating deep stabilizing muscles on posture and quality of respiratory movements. Deep muscles play an important role in postural control. The activity of these muscles contributes directly to joint stiffness—the greater the stiffness is, the more stable the structure is (O'Sullivan, 2000; Sangwan, Green, & Taylor, 2014). Reduced deep muscle activity of the lower trunk triggers compensatory posture and movement patterns. The specific pattern of compensation resulting from lack of tension in the deep stabilizers of the lower trunk is associated with the overuse of superficial (global) muscles and changes in the position of the body segments (Gogola, Saulicz, Kuszewski, Matyja, & Myśliwiec, 2014). For this reason, many authors see the need to strengthen deep muscles in the re-education of postural control. However, searching the literature for information on the effects of deep muscle training on postural change has not yielded satisfactory results. The majority of works focus on evaluating the activity of these muscles in people with pain in the lumbar spine. As far as we know, this study is, therefore, the first to show the effect of exercising deep muscles on both posture and respiration. Kim and Lee (2013) tried to determine the effects of enhanced diaphragmatic function, achieved through deep abdominal muscle strengthening exercises, on respiratory function and lumbar stability. Assessed variables were forced vital capacity and forced expiratory volume for 1 s. Lumbar stability was measured based on the contractility of the transversus abdominis by using a pressure biofeedback unit. Participants in their study realized a program of exercises of the transversus abdominis and assessed the strength of this muscle in the hook-lying position. In our program, we used exercises in different positions and the assessment of posture and movement of the chest was made in the freestanding position, bearing in mind this is a more functional position.

FIGURE 5. Image of the participant performing exercise on the ball with elevated leg.

The exercises we used mainly activated transverse abdominal muscles as well as multifidus and internal oblique muscles. The results confirmed the effect of deep muscle training on improved postural control. Although our observations were related to the position of the head, torso, and pelvis, the applied exercises only positively affected control of the trunk in the sagittal plane. In our opinion,

TABLE 2. Descriptive Statistics of the Examined Parameters of Posture and Breathing Before and After Exercising Deep Muscles as well as Differences in Spatial Position of Selected Segments of the Posture and Breathing Amplitude Before and After Exercising Deep Muscles

	Before Mean ± SD	After Mean ± SD	Student's *t* test	*p*	Wilcoxon test	*p*
Sagittal (°)						
Head posture	85.32 ± 6.50	84.73 ± 7.17	−0.302	.7660		
Pelvic posture	83.20 ± 8.71	82.17 ± 4.18	−0.711	.4267		
Trunk posture	176.51 ± 3.95	179.16 ± 3.20	3.015	.0078*		
Frontal (°)						
Head posture	91.09 ± 2.81	90.04 ± 2.15	−1.972	.0651		
Pelvis posture	90.06 ± 1.85	90.27 ± 1.79			0.784	.4331
Trunk posture	179.73 ± 1.61	179.97 ± 2.67			0.065	.9479
TE Avp (mV)	565.41 ± 221.99	673.80 ± 314.83			1.590	.1119
AE Avp (mV)	399.02 ± 191.60	553.78 ± 214.01			3.593	.0003*

Note. AE = abdominal excursion; Avp = amplitude of breath; TE = thoracic excursion.
*$p < .05$; df = 17.

such a relationship may be explained by the kind of exercises applied, which activated only the stabilizing muscles of the lower trunk. Any future program should include exercises to improve control of the head and upper body (e.g. activation of serratus anterior).

Postural control and breathing are mechanically and neuromuscularly interdependent (Hudson, Butler, Gandevia, & De Troyer, 2010). Both systems—of spinal stability and respiration—involve the same muscles, being the diaphragm, transversus abdominis, intercostal muscles, internal oblique muscle, and pelvic floor muscles (Hodges et al., 2001). Among others, Kolar et al. (2012) claimed that a normal breathing pattern requires a stable lower trunk. The structure connecting a stable trunk with breathing is the diaphragm, but the diaphragm does not participate homogeneously as a functional unit in stabilization. Smith, Russel, and Hodges (2006) found a significant correlation between the diaphragm and transversus abdominis that simultaneously control both respiration and posture. Kim and Lee (2013) indicated that deep abdominal muscle strengthening exercise was effective at increasing vital capacity. The study by Park, Kweon, and Hong (2015) is also noteworthy in this respect. Its results showed improved lumbar stability with increased transversus abdominis contractility after four weeks of deep breathing exercises . In light of our findings, we can say that the previously indicated relationship works both ways. Our results confirmed the effect of exercising the muscles stabilizing the lower

TABLE 3. Dependency Test Results between the Parameters of Photogrammetry and Breathing as a Difference between the Value of the Parameter Measured Before Exercise and After Exercising Deep Muscles

		Spearman's rank correlation coefficient	*p*	Pearson line correlation coefficient	*p*
Sagittal					
Head posture	TE Avp			−0.027	.9166
	AE Avp	−0.032	.8997		
Pelvic posture	TE Avp			−0.271	.2218
	AE Avp	−0.207	.2185		
Trunk posture	TE Avp			0.597	.0089*
	AE Avp	0.063	.8040		
Frontal					
Head posture	TE Avp			−0.055	.8276
	AE Avp	0.017	.9481		
Pelvic posture	TE Avp			0.032	.8992
	AE Avp	−0.176	.4836		
Trunk posture	TE Avp			0.091	.7198
	AE Avp	0.189	.4529		

Note. AE = abdominal excursion; Avp = amplitude of breath; TE = thoracic excursion.
*$p < .05$; df = 16.

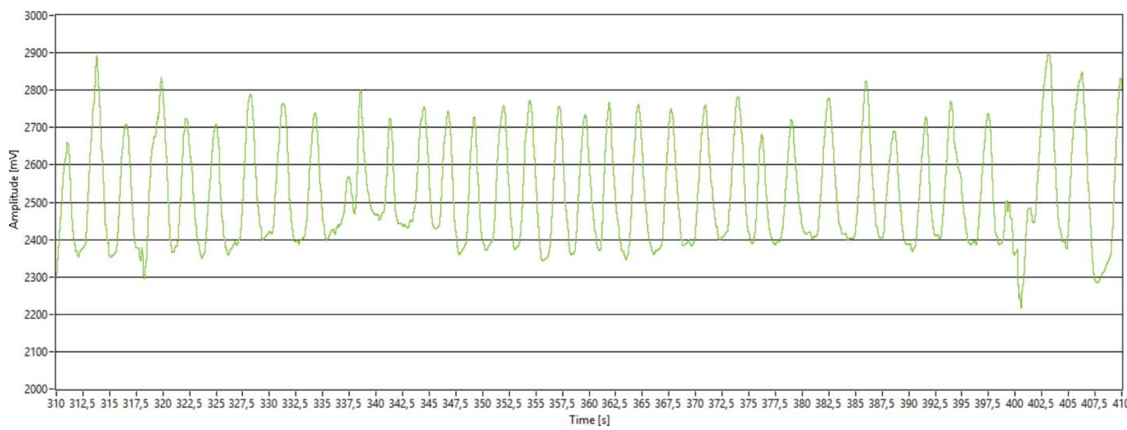

FIGURE 6. Examples of records of the abdominal excursion of one participant before exercises (*M* amplitude = 240 mV).

trunk on both posture quality and the amplitude of respiratory movements. Applied deep trunk muscle training contributed significantly to an increase in the amplitude of the abdominal excursion and modified the spatial position of the torso. Abnormal breathing stereotype, known as thoracic breathing, involves breathing from the upper chest, evidenced by greater upper rib cage motion, compared with the lower rib cage. Thoracic breathing is produced by the accessory muscles of respiration (including sternocleidomastoid, upper trapezius, and scalene muscles), dominating over lower rib cage and abdominal motion (Chaitow, Bradley, & Gilbert, 2002). Vickery (2008) suggested that decreased abdominal motion, relative to upper thoracic motion, confirms poor diaphragm action. In our study, the observed changes in chest excursion can be a confirmation of improvement of breathing pattern. However, we cannot give a straight answer to the question if the increase in the amplitude of the abdominal excursion was related to the increase in the activity of the diaphragm during the training, or rather to the change in the torso position. Strongoli, Christopher, Gomez, and Coast (2010) reported increased diaphragm activation, evidenced by increased transdiaphragmatic pressure during core exercises in six healthy participants. They were instructed to inhale during the exertion phase to elicit a higher and more consistent transdiaphragmatic pressure. In other reports, similarly, authors added instructions regarding breathing or introduced special breathing exercises (Kim & Lee, 2013).

Cavaggioni, Ongaro, Zannin, Iaia, and Alberti (2015) demonstrated that, compared with traditional exercises, a program including core exercises performed with a focus on muscular chain stretching and breathing techniques can lead to greater improvement in respiratory function (measured by forced vital capacity, forced expiratory volume in 1 s, and peak expiratory flow). A group of 32 healthy participants participated in the program. Applied exercises

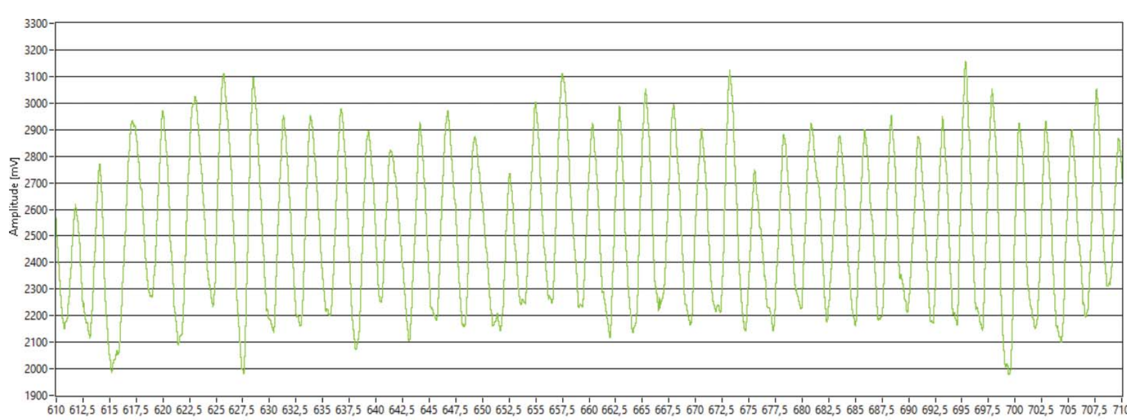

FIGURE 7. Examples of records of the abdominal excursion of the same participant after exercises (*M* amplitude = 390 mV).

were focused on achieving and maintaining a proper diaphragmatic breathing pattern for 2–3 s during inspiration and 8–10 s during expiration, with a vocal sound emitted to induce active recruitment of the pelvic floor muscles and deep internal abdominals. Their results suggested that a series of core exercises performed with a vocal sound emission can be a valid strategy to enhance proper diaphragmatic breathing patterns and deep internal abdominal activation much more than in traditional abdominal routines in which people tend to hold their breath or use chest wall respiration. In our group, we did not educate the participants of the training about how they were supposed to breathe. Also, we did not introduce any special breathing exercises, thus allowing the participants to breathe in their natural way.

On the other hand, we should underline that, after the exercises, the values of the angle describing the position of the torso in the sagittal plane were close to 180°, which indicates a better control of the torso (Table 2). We also noticed that the higher the difference between after-exercise and pre-exercise values in the measurement of the body position parameter in the sagittal plane, the higher the difference between after-exercise and pre-exercise values in the measurement of the amplitude in the abdominal excursion.

Among the tested posture parameters, a significant correlation occurred between the amplitude of breathing and trunk position. Undoubtedly, the position of the trunk is related to both rib tilting and muscle activity involved in stabilization and breathing. Kolar and colleagues (Kolar & Kobesova, 2010; Kolar, Kobesova, Valouchova, & Bitnar, 2014) have said that, in the normal pattern of breathing, the thorax should be positioned so that the anteroposterior axis between the insertion of the diaphragm's pars sternalis and the posterior costophrenic angle is almost horizontal. The forward drawn position of the chest or apex of the T kyphosis situated behind the L/S junction present other abnormalities preventing ideal muscle balance and proper stabilization (Kolar & Kobesova, 2010; Kolar et al., 2014). We believe that changing the setting of the trunk in the sagittal plane corresponds with the course of this axis, which may explain the correlation that we have observed. Therefore, the change in the spatial position of the torso that we observed could also have influenced the increase in the amplitude of breathing movements. We expected that our studies would confirm the effect of head setting on the mobility of the chest. We observed relationship previously (Szczygieł et al., 2015) during tests using 65 participants. Unfortunately, we have found no such relationship. Perhaps this was due to the small sample size of the study group and the fact that the exercises mainly activated the muscles stabilizing the lower trunk. We have not used exercise to improve head control.

Limitations of the present study can be the fact that we focused on the biomechanical aspect of breathing and did not measure the pulmonary function. In the future, it would be reasonable to consider the evaluation of the influence of deep muscle training not only on breath amplitude, but also on the change in the tidal volume parameter.

Conclusion

Deep muscle training improves control of trunk and respiratory control. Posture and breathing stereotype forms a functional unit and is strongly influenced by the thorax position.

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