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Original research article

BREATHING EXERCISE AND CORRECTION OF THE POSTURAL STEREOTYPE

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Abstract. *The purpose of this paper was to evaluate the effectiveness of breathing exercise in a seated position in a wheelchair on postural stereotype and assessment of further objective indicators. The sample consisted of 15 participants with spinal cord injury (SCI), 8 men and 7 women. The intervention program lasted for six months, five times a week, in the range of 20 - 30 minutes. The study included: 1) the Chest X-Ray in a seated position during inhalation and exhalation; 2) chest excursion; 3) determination of forced vital capacity (FVC) and forced expiratory volume during the first second (FEV1); 4) the wheelchair treadmill test to identify oxygen uptake (VO2) and maximum minute ventilation (Vmax). The pretest X-ray showed that the difference in the movement of the lower ribs during inhalation and exhalation was 2-35 mm. The measurement of chest circumference showed a limitation of chest expansion related to normal values connected with age and sex. Tetraplegics FVC decreased by 30-50 % compared with the values of the healthy population and paraplegics FVC reduced by about 80 %. The wheelchair treadmill test showed that VO2 for all persons with SCI were above average (0.89) compared to the values of the population without disabilities. V max for all persons with spinal cord injury was also above average (38.22). After six months, the X-ray examination showed that the difference in the movement of the lower ribs during inhalation and exhalation has increased by 49 % (6 to 45 mm). The circumference of chest during inspiration increased by 3.5 % and during exhalation decreased by 1.27 %. FEV1 increased by 5.68 % and FVC increased by 7.61%. VO2 decreased, with an average value of 0.67. Vmax remained unchanged (graph 2). In this study, by using the X-ray and other tests, we have noted the objective influence of breathing exercises which affect posture on the main respiratory muscles in persons with SCI.*

Key words: *breathing exercises, spinal cord injury, X-ray, posture.*

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INTRODUCTION

Spinal cord injury (SCI) often leads to impaired breathing. In most cases, such severe respiratory complications lead to morbidity and death. However, in the last few years there has been extensive work examining ways to restore this vital function after experimental spinal cord injury. In addition to finding strategies to preserve breathing activity, many of these experiments have also yielded a great deal of information about the innate plasticity and capacity for adaptation in the respiratory system and its associated circuitry in the spinal cord.

People with SCI frequently experience a range of complications. Respiratory dysfunction (Chen, Lien & Wu, 1990), pain (Dyson-Hudson & Kirshblum, 2004; Gironda, Clark, Neugaardm & Nelson, 2004), muscle fatigue (Rodgers, McQuade, Rasch, Keyser & Finley, 2003), and pressure ulcers (McKinley, Jackson, Cardenas, & DeVivo 1999; Thorfinn, Sjöberg & Lidman, 2002) are among the most common complaints. A major cause of morbidity and mortality among this group of people is long-term respiratory complication in the form of pneumonia or atelectasis5, with pneumonia being the leading cause of their deaths (Jackson & Grooms, 1994).

Many factors can contribute to poor lung function, including smoking habits, surgical history, hazardous occupational or environmental exposure, asthma, allergies, chronic obstructive pulmonary disease, and obesity. Additionally, the connection between posture and lung performance has proved significant (Chen, 1990; Hobson & Tooms, 1992; Baydur, Adkins & Milic-Emili, 2001; Lalloo, Becklake & Goldsmith, 1991).

In the SCI populations, Chen (1990) and Baydur et al., (2001) found that the supine posture produced the best spirometric recordings. But since subjects with SCI are in a seated posture for prolonged periods of time, it is important to know how different seated postures affect pulmonary function. A new seated position that changes the ischial and lumbar support (Makhsous, Patel, Lin, Hendrix, Hepler & Zhang, 2003) has been developed to suggest a new seated posture to mimic the spine’s natural curvature in the stance, and provide better postural support for seated subjects (Makhsous et al., 2003). This posture has been linked to the back part of the seat without ischial support (WO-BPS), (Makhsous, Patel, Lin, Hendrix & Zhang 2003) and the enhanced lumbar support. Because the WO-BPS design imitates a standing spinal alignment, it was expected that the use of this model by subjects would result in improved seated posture and respiratory capacity. This study was already performed on healthy individuals and the purpose of this study is to determine the effect of these postural changes on lung capacity and expiratory flow in spinal cord injury patients.

The coordination between respiratory and postural functions of the diaphragm was investigated during repetitive upper limb movement. It was hypothesized that diaphragm activity would occur either tonically or phasically in association with the forces from each movement, and that this activity would combine with phasic respiratory activity of the diaphragm. This has been studied by several authors who have demonstrated that diaphragmatic activity can assist with mechanical stabilization of the trunk along with concurrent maintenance of ventilation (Bouisset & Duchene, 1994; Gandevia, Butler, Hodges & Taylor, 2002; Hodges, Butler, McKenzie & Gandevia, 1997; Saunders, Rath & Hodges, 2004). The diaphragm contributes to postural control during trunk stabilization (Hodges et al., 1997) and voluntary limb movement (Hodges & Gandevia, 2000). The diaphragm and abdominal muscles together create a hydraulic effect in the abdominal cavity, which assists spinal stabilization (Kolař et al., 2009; Miyamoto, Shimizu, & Masuda, 2002) by stiffening the lumbar spine through increased intra-abdominal pressure (Hodges, Eriksson, Shirley & Gandevia, 2005). Therefore, poor coordination of the diaphragm and abdominal muscles may result in compromised stability and dysfunction of the lumbar spine.

After an injury at a high point on the SCI, the muscles responsible for breathing are paralyzed or weakened. This weakness reduces the volume of the lungs (lung capacity), the ability to take a deep breath and cough, and puts the individuals at a greater risk of lung infection. Just like other muscles of the body, it is possible to train the breathing (respiratory) muscles to be stronger; however, it is not clear if such training is effective for people with SCI.

The study of Van Hout, Vanlandewijck & Gosselink (2006) says that impaired respiratory muscle function and increased risk of respiratory complications have been frequently mentioned as indications for respiratory muscle training (RMT) in persons with SCI. In addition, it is well established that a person with quadriplegia suffers from a reduce physical capacity due to the loss of motor function in the lower and/or upper limbs and the relatively inactive lifestyle associated with the injury. In addition, respiratory muscles might partake in non-ventilatory function during exercise. Therefore, it is assumable that exercise performance might benefit from RMT in persons with SCI.

This article will highlight the results of our study in people with spinal cord injury. We will show the results of disturbance of breathing, the various methods of breathing exercise after such injury, and some recent findings from our study.

THE METHOD

A pilot study was conducted in collaboration with the "Centre Paraple" as a part of the "Healthy Lifestyle". Fifteen participants with SCI took part in this study: 8 men and 7 women: high tetraplegia (C4 and C5) - 3 persons, low tetraplegia (C6 - C8) - 6 people, high paraplegia (Th1 - Th6) - 2 persons, low paraplegia (Th7 and below) - 4 people. The age limit was 24-60 years. On average, each person had been injured 3-15 years ago. Four persons of fifteen smoked, on average for 23.5 years. The study lasted for six months, five days a week with a frequency in the range of 20-30 minutes.

This study was approved by the ethics committee. All of the participants were questioned to ensure that they met the inclusion criteria of the study. All testing procedures were thoroughly explained to the participants with a detailed description of the X-ray and spirometry assessments. All of the participants reported that they understood the test procedures and gave their informed consent.

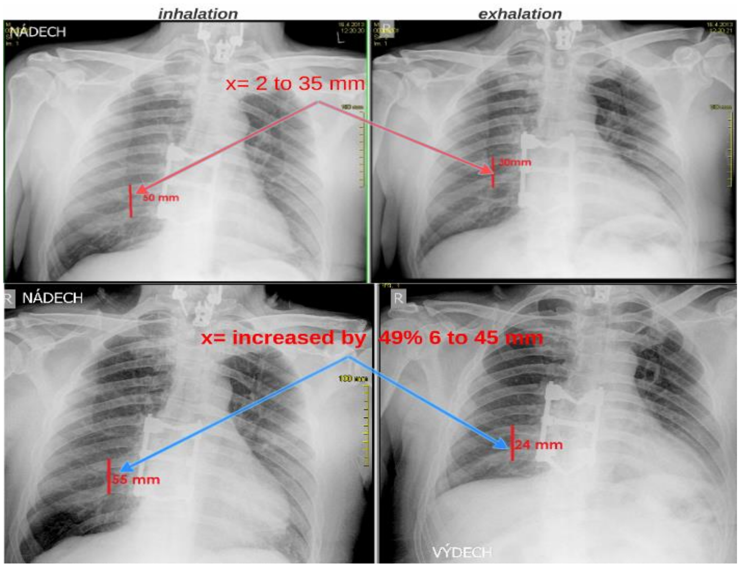
Within the study, the following tests were carried out tests, including:

- An X-ray examination of the lungs in a seated position - we observed differential movement of the lower ribs on the inhale and exhale (Pic. 1).
- Excursion chest - chest circumference was measured with a measuring tape - in front of the nipples (men) or of the mezosternal (women) and back under the lower angles of the blades. The circumference was measured at the mid-breath position, then after maximum inspiration and then after maximum expiration.
- Spirometry parameters, forced vital lung capacity (FVC) and one-second forced expiratory (FEV1) were determined by the spirometric system Micro Diary Card (Micro Medical Ltd., UK).
- For the assessment of additional objective indicators, we conducted the Wheelchair Treadmill Test to identify Oxygen uptake (VO2) and maximum ventilation (Vmax [$l.min^{-1}$]). Speed increased by 0.2 km in 12s, submax. 4 min., at a constant grade (5%).

Before the start of the experiment, we have carefully studied the theoretical basis for the evaluation methodology of breathing exercises. Based on the relations established during measurement and clinical observation, the breath exercise program focused on major and minor respiratory muscles. For example, one exercise from the program: **"Bellows"**: Rapid breath - a sharp exhale, pushing the abdomen and diaphragm. At the beginning we were recommending a slightly slower rate (1 breath every 2 sec.) and gradually increased the speed and number of breaths (1 breath and exhale 1). The participants started with five breaths. The number of breaths depended on the lungs and their ability to make a big breath and exhale. Then, when participant had mastered the basic exercises, every day two to three rounds were added, until he reached the number of 60 laps per session. Once any sign of fatigue or hyperventilation was determined, the exercise was completed and postponed until the next day, when the testing started with a lower number of rounds.

RESULTS

For the data analysis, we used the program NCSS. After each examination, we used a graphical representation (box plot) to represent the decomposition of the results in the pre-test and post-test, which made it easy to see whether there was any expected change - improvement or not. The pretest X-ray examination showed that the difference in vertical movement of the lower ribs during inhalation and exhalation was 2-35 mm (Fig. 7). The results of the wheelchair treadmill test showed that VO2 for all persons with spinal cord injury were above average. The average value was 0.89 [l. min^{-1}] (Fig.1) compared with the values of the population without disabilities. V max for all persons with spinal cord injury were also above average (38.22) compared with the values of the healthy population (typical value: 120-180 L/min), (Fig. 2). The vital lung capacity was somewhat lower than in the unaffected population (Fig. 3, 4). Measuring the circumference of the chest showed little difference between the indices (maximum inhalation and exhalation) indicating the excursion of the chest (Fig. 5, 6). These indices are equal to about 3 cm, which means reduced chest excursion.



Picture 1 The radiograph of the lungs pre-test post-test

After six months, we repeated the tests. The X-ray examination showed that the difference in the movement of the lower ribs on the inhale and exhale increased by 49%, or 6-45 mm (Fig. 7). The circumference of the chest during inspiration increased by 3.5% (Fig. 5) and the chest circumference during exhalation decreased by 1.27% (graph 6). One second vital capacity increased by 5.68% (Fig. 3) and forced vital capacity of the lungs of 7.61% (Fig. 4). VO2 was on average decreased, average value was 0.67 [l. min^{-1}] (Fig. 1). Maximum ventilation remained unchanged (Fig. 2).

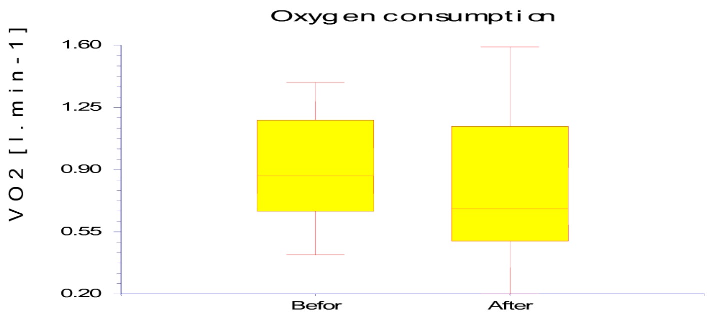


Fig. 1 Graphical comparison of the difference in the index oxygen consumption on the pretest and post-test

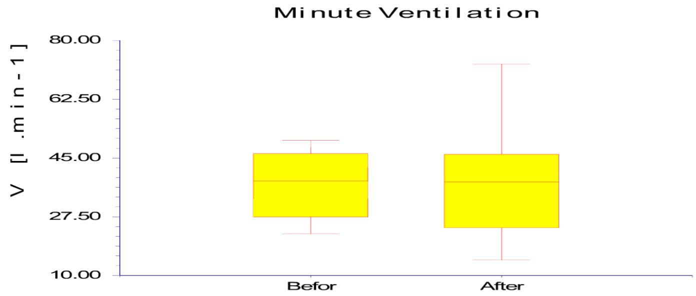


Fig. 2 Minute ventilation in the pretest and post-test

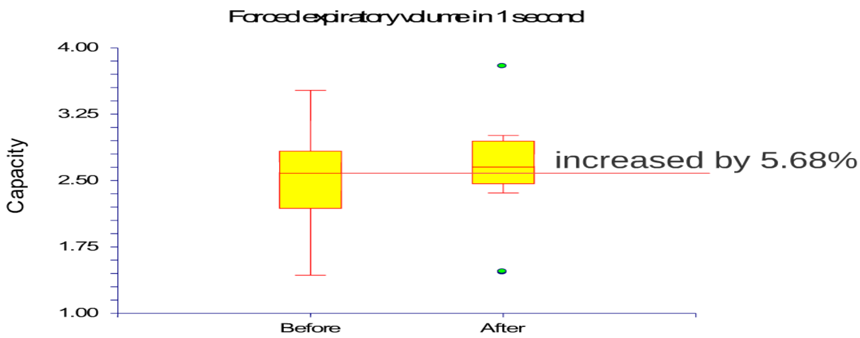


Fig. 3 One-second forced expiratory pretest and post-test

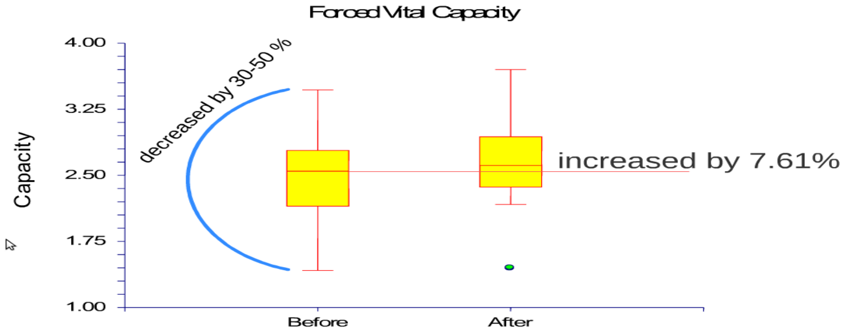


Fig. 4 Forced vital capacity of the lungs pretest and post-test

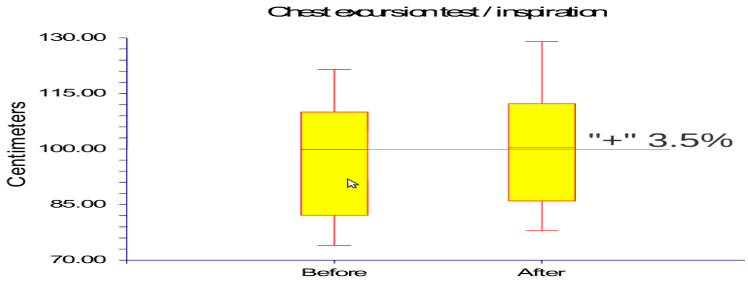


Fig. 5 Circumference of the chest during inspiration

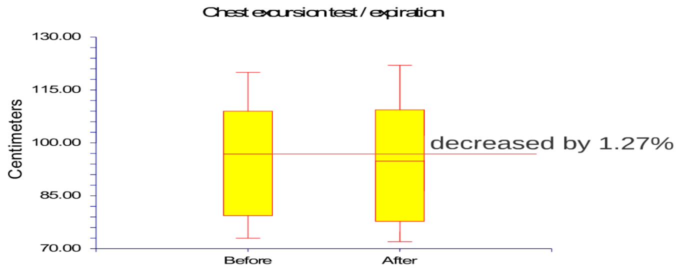


Fig. 6 Chest circumference during exhalation

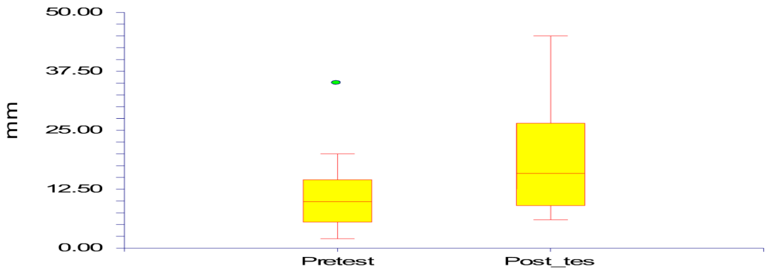


Fig. 7 The radiograph of the lungs pre-test **and** post-test

DISCUSSION

This study showed that respiratory muscles in individuals with PM can be trained as in the healthy population. These data are consistent with previous studies summarized by Brown, DiMarco, Hoit, & Garshick (2006). The assumption that breathing exercises have a positive meaning for people with SCI was confirmed by our measurements. This is demonstrated by measuring the difference between the movement of the lower ribs during inhalation and exhalation, which was determined by means of an X-ray examination of the lungs. With these results, it can be assumed that the breathing exercises affect not only the intercostal muscles, but also other major respiratory muscles and accessory respiratory muscles. From the X-ray images we can see the increased movement of the diaphragm. From the above mentioned, we can conclude that it improves the strength of the diaphragm, as was the case in the study of Kogan et al. (1996), and that it leads to a more active lifting of the ribs, which affects posture (Velé, 2006). There is a clear relationship between respiration and posture, which was confirmed in our study and studies that we mentioned earlier (Chen et al., 1990; Baydur et al., 2001; Gandevia et al., 2002; Makhsous et al., 2003). Nevertheless, we did not register changes during the wheelchair treadmill test. It can be assumed that the breathing exercises have no effect on pulmonary ventilation and oxygen consumption, and in some cases measurable value actually declined. However, none of the persons observed by Kogan et al., who attained the benefits of training decided to continue the practice training of breathing muscles after the end of the study. A similar situation also occurred in our study. It was very difficult to keep the motivation level of people with SCI, to properly perform the breathing exercises and increase their belief in a positive outcome. From this perspective, it would be appropriate to examine this problem and establish a relationship between the object (breathing exercises) and an entity (person with SCI).

CONCLUSION

The results of the study showed a positive influence of breathing exercises on people with SCI. The limiting factor in our study may be the focus of the study which only included a specific part of the population; therefore, we cannot generalize the results completely. The positive importance of breathing exercises for people with PM is not negligible. Breathing exercises positively affect the chest excursion and spirometric parameters of persons with SCI. As we found out that breathing exercises in probands of this study affect the respiratory muscles, it is likely that these exercises have a formative character on sitting posture which in turn affect other functions and internal organs.

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VEŽBE DISANJA I ISPRAVLJANJE STEREOTIPNOG DRŽANJA TELA

Cilj istraživanja bio je da se proceni efikasnost vežbi disanja u sedećem položaju kod osoba u kolicima na stereotipno držanja tela i da se procene drugi objektivni indiktori. Uzorak ispitanika činilo je 15 osoba sa oštećenjem kičmene moždine, (SCI), 8 muškaraca i 7 žena. Eksperimentalni program trajao je šest meseci, i sprovodio se pet puta nedeljno u trajanju od 20 - 30 minuta. Istraživanje je uključilo: 1) rendgenski snimak grudnog koša u sedećem poožaju tokom udisaja i izdisaja; 2) pomeranje dijafragme; 3) određivanje maksimalnog izdisaja (FVC) i maksimalnog izdisaja tokom prve sekunde (FEV1); 4) pokretna traka za osobe u kolicima kako bi se odredila maksimalna količina vazduha koja se udiše tokom vežbanja (VO2) i maksimalni broj udisaja tokom jednog minuta (Vmax). Rendgenski snimak tokom pretesta pokazao je da je razlika u pokretanju donjeg dela grudnog koša tokom udisaja i izdijsanja bila u rasponu od 2-35 mm. Merenje obima grudnog koša pokazalo je da je ograničenje u ekstenziji grudnog koža u skladu sa godinama i polom ispitanika. FVC kod tetraplegičara smanjio se je za 30-50 % u poređenju sa zdravom populacijom, a FVC paraplegičara smanjio se za oko 80 %. Na pokretnoj traci za osobe u kolicima utvrđeno je da je VO2 za sve osobe koje boluju od SCI iznad proseka (0.89) u poređenju sa vrednostima populacije bez ovih problema. V max za sve osobe sa oštećenjem kičmene moždine je takođe bilo iznad prosečnih vrednosti (38.22). Nakon isteka 6 meseci, rendgenski snimak pokazao je da se je razlika u pokretanju donjeg dela grudnog koša tokom udisaja i izdisaja povećala za 49 % (6 to 45 mm). Obim grudnog koša tokom udisaja povećao se je za 3.5 % a tokom izdisaja se smajio za 1.27 %. Za FEV1 je zabeleženo povećanje od 5.68 % , a FVC umanjenje za 7.61%. VO2 se je smanjio, sa prosečnom vrednosti od 0.67. Vmax ostao je nepromenjen (grafikon 2). U ovom istraživanju, upotrebom rendgenskog snimanja i drugih testova, uočen je objektivan uticaj vežbi disanja vezanih za držanje tela na glavne mišiće odgovorne za disanje kod osoba sa SCI.

Ključne reči: *vežbe disanja, oštećenje kičmene moždine, rendgenski snimak, držanje tela..*