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Original Research

Acute effects of breathing exercises on diaphragmatic mobility and respiratory muscles activity in healthy adults

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Abstract

Objective: To investigate the differences between the breathing exercises sniff inspiration (SI), diaphragmatic breathing (DB), fractionated breaths (FB) and breathing from functional residual capacity (BFRC) in terms of their effect on diaphragmatic mobility and electrical activity of the sternocleidomastoid (SCM) and anterior scalene muscles in healthy adults in two positions: sitting and supported 30° trunk inclination. **Methods**: In a cross-sectional observational research, healthy adults of both sexes were recruited. Participants underwent anthropometric and spirometric assessment and their vital signs were measured. Diaphragmatic mobility (DM) was analyzed by ultrasound (US). Electrical activity of the sternocleidomastoid and anterior scalene muscles was assessed by electromyography (EM), in two positions: sitting and supported 30° trunk inclination. **Results**: A total of 30 individuals were assessed, 14 women and 16 men. Among the exercises studied, respiratory muscles were least used in DB for both positions and most used in BFRC. In regard to DM, the exercise that mobilized the diaphragm the most was BFRC in both studied positions, while DB caused the least mobilization of this muscle. Diaphragmatic mobility declined during trunk inclination at 30° and respiratory muscle electrical activity was lower when compared to the sitting position. **Conclusion**: In clinical practice, diaphragmatic breathing proved to be the exercise that least used the respiratory muscles. However, the BFRC with a 30° trunk inclination is the most recommended exercise when the objective is the mobilization of the diaphragm. It is important to know the muscle action during breathing exercises for a better prescription.

Keywords: Breathing Exercises; Diaphragm; Electromyography.

How to cite

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How can the results of this study be used in clinical practice?

- Diaphragmatic breathing caused less activation of the respiratory muscles in relation to other exercises, which is relevant information to a better understanding of the muscle action during breathing exercises.
- Understanding the characteristics of diaphragmatic mobility and respiratory muscle activity during the execution of breathing exercises may contribute to a better prescription of these exercises in clinical practice.

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Introduction

Breathing exercises are aimed at optimizing the action of respiratory muscles, especially the diaphragm, as well as ventilating different regions of the lungs. In clinical practice, one of the main objectives of physiotherapists is to improve the function of the diaphragm muscle. Diaphragmatic breathing (DB) is the most widely used breathing exercise in physiotherapy protocols because it increases the recruitment of diaphragm muscle fibers, improves diaphragmatic mobility, expands the lower chest region, promotes greater abdominal motion, and contributes to the tidal volume and vital capacity of individuals[1,2].

In addition to DB, inspiratory sighs (SI) exercises, fractionated breaths (FB) and breathing from functional residual capacity (BFRC) were developed to stimulate the action of the diaphragm and favor lung expansion and diaphragmatic mobility (DM)[3]. However, few studies have assessed the influence of breathing exercises on the respiratory muscles. In clinical practice, the knowledge of muscle action is essential for good prescription of respiratory exercises.

When analyzing[4] the electrical activity of the diaphragm, sternocleidomastoid (SCM), scalene and external intercostal muscles during DB versus feedback breathing in patients with chronic obstructive pulmonary disease (COPD), a decline in the electrical activity of sternocleidomastoid and scalene muscles during DB was observed. Other studies[5] analyzed the electrical activity of the diaphragm and external intercostal muscles during DB in patients with COPD and reported a decline in intercostal muscles activity during that exercise. The effects of three breathing exercises were compared: 1) deep breathing, 2) flow-oriented spirometry and 3) volume-oriented spirometry in healthy adults on the electrical activity of the diaphragm, external intercostal, sternocleidomastoid and scalene muscles in two different positions (sitting and forward leaning at 45º). The results showed lower electrical activity in the sternocleidomastoid and external intercostals for forward leaning at 45° and, when compared to the exercises, electrical activity in all four muscle groups was lower during volume-oriented spirometry[6].

In light of the above, although there are studies in the literature involving several breathing exercises routinely used in clinical practice, other lesser known exercises should also be investigated to determine which one(s) best stimulates DM and less affects the electrical activity of respiratory muscles. This is especially important when the aim in clinical practice is to use exercises that least activate this musculature. As such, this study aimed to assess acute effects of breathing exercises: sniff inspiration, fractionated breaths and breathing from functional residual capacity on diaphragm mobility, as well as the electrical activity of sternocleidomastoid and anterior scalene muscles in heathy adults, while sitting and at 30° trunk inclination.

Material and methods

This is an observational cross-sectional study with a quantitative approach, approved by the Research Ethics Committee of Santa Catarina State University (69929517.7.0000.0118).

A convenience sample was composed by volunteers of a sample calculation from a pilot study with the first 10 individuals. For the calculation, the following variables were considered: diaphragmatic mobility (cm), percentage of contribution of the sternocleidomastoid muscle, and percentage of contribution of the scalene muscle in relation to Maximum Voluntary Isometric Contraction (MVIC). The size of the effect was estimated through the square root of the sum of the squares of the factor, divided by the sum of the squares of the error. The significance level considered was 5%, with a statistical power of 0.80 resulting in 30 individuals. Inclusion criteria were healthy individuals from both sexes, aged between 18 and 65 years, with normal body mass index (BMI) values. Those with difficulty to understand and execute the proposed exercises were excluded. All participants provided written informed consent and filled out a registration form compiled by the researchers specifically for this study.

Subjects were then submitted to anthropometric and dyspnea assessment, and the following cardiorespiratory parameters were measured: blood pressure (BP), heart rate (HR), respiratory rate (*f*), and peripheral oxygen saturation (SpO_2). This was followed by lung function testing. Next, participants were familiarized with the proposed breathing exercises, using a set of ten repetitions of each exercise randomly described in the protocol (DB, SI, FB and BFRC). After familiarization, a draw was conducted using the Lucky Wheel Lucky Draw cellphone application to define the order of exercises and positions.

For assessments in the sitting position, individuals were seated with their trunk supported by the standard chair for this evaluation, with their hips at a 90º angle to the trunk, knees flexed at 90º, feet flat on the floor, arms relaxed and hands on their thighs. For dorsal decubitus with 30º trunk inclination, participants were lying on a standard physiotherapy table with their trunk supported on a triangular wedge at an angle of 30º, arms relaxed alongside their bodies, knees semi-flexed and resting on an orthopedic positioning roll.

At each series of breathing exercises, DM was measured (3 repetitions of the exercise randomly selected) and the electromyographic signal (EMG) of the sternocleidomastoid and scalene muscles analyzed. Then, 10 repetitions of the same exercise were performed, recording the EMG signal. Afterwards, DM was measured again (3 repetitions) and the EMG signal captured at each repetition. The number of repetitions of each exercise was 10, the same number usually used in clinical practice[7,8]. The protocol is summarized in Figure 1.

The verbal commands for performing the exercises were as follows: for the diaphragmatic exercise, a soft and deep nasal inspiration was requested, prioritizing the anterior displacement of the abdominal region, avoiding the displacement of the rib cage[9]. To perform the sniff inspiration exercise, brief, successive and slow nasal inspirations were

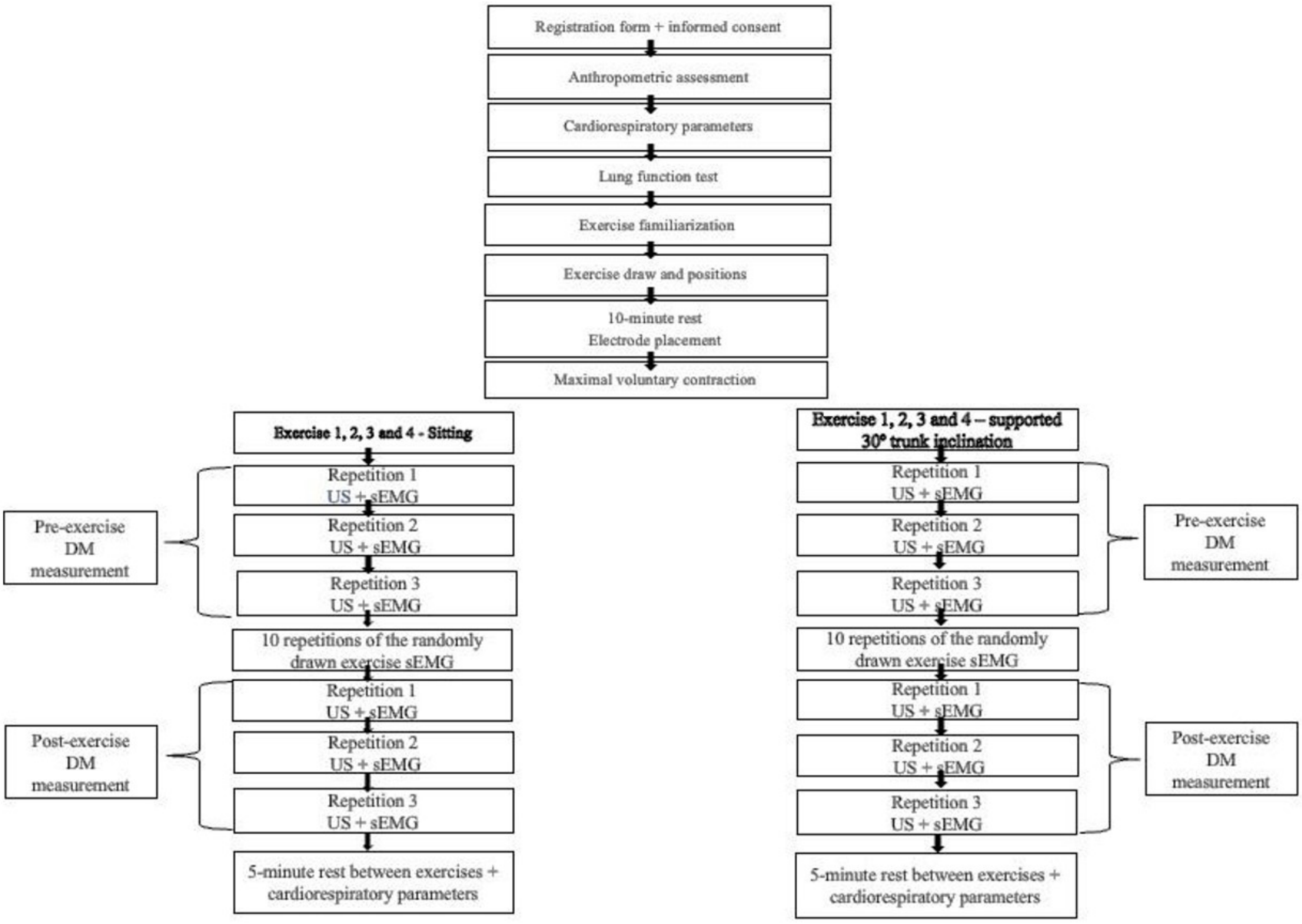

Figure 1. Protocol of the study.

requested until reaching the total inspiratory capacity, and the last inspiration was performed orally, with normal expiration[10]. In order to perform the exercise fractionated breaths, 4 gentle nasal inspirations were requested, interrupted with periods of post-inspiratory pause, about 2 to 3 seconds, until total lung capacity, ending with oral expiration[11]. To perform the exercise breathing from functional residual capacity, a quiet oral expiration was performed until the level of expiratory rest, followed by a fast and strong inspiration until close to the inspiratory reserve volume (IRV)[3,10].

Surface electromyography (sEMG) and signal processing for muscle activation were carried out in line with the recommendations of the International Society of Electrophysiology and Kinesiology (ISEK) and Surface Electromyography for Noninvasive Assessment of Muscles (SENIAM). The analysis was performed with a MYOMUSCLE v3.6 sEMG system (NORAXON, USA), using the bipolar technique and a bandpass filter at a frequency of 10 – 50 MH. Signal normalization was established by a MVIC.

The electrodes were positioned on the sternocleidomastoid muscle belly, five centimeters below the mastoid process, and on the posterior triangle of the neck at the level of the cricoid cartilage, on the lower portion of the anterior scalene muscle. The sEMG signals were analyzed and processed using the root mean square (RMS)[12-15].

Diaphragmatic mobility was evaluated using a Sonosite Nanomax portable ultrasound (US) (Bothell, WA, USA), with a 2-5 MHz transducer positioned anteriorly in the subcostal region and at a slight angle in the cranial direction to reach the posterior third of the right hemidiaphragm. The DM value was calculated based on the range of movement of the diaphragm during the 4 separate exercises. The inspiratory and expiratory peaks of each respiratory cycle were recorded. Participants performed 3 repetitions of each exercise, with mobility captured for each repetition. The highest result of the 3 values obtained with less than a 10% difference between them was used, and expressed in centimeters[7,8].

Data were analyzed and processed by the IBM SPSS Statistics program (Statistical Package for the Social Sciences), version 20.0. The Shapiro-Wilk test was used to analyze normal data distribution, followed by two-way repeated measures ANOVA with Bonferroni's post-hoc. Two-way repeated measures ANOVA was used to verify whether there were differences between exercises and postures, with Bonferroni Post hoc for the main variable diaphragmatic mobility, and secondary variables: percentage of electrical activity contribution of the sternocleidomastoid muscle and percentage of contribution of activity of the scalene muscle. The significance level adopted was 5%.

Results

Thirty-four individuals were recruited for the study, and 30 were studied with a mean age of 27 years, 1,70m in height, BMI and spirometric values within the normal range. Four individuals were excluded from the study because they did not present spirometric values within the normal range. Sample characterization data are shown in Table 1.

Individual analysis of the two positions indicated a significant difference (P<0.001) during the four studied breathing exercises. The analysis of the interaction between positions and exercises showed that the BFRC exercises exhibited greater diaphragmatic mobility than those recorded during DB in both positions (P = 0.05) (Figure 2).

Comparison of the electrical activity of the sternocleidomastoid muscles during the exercises in both positions indicated a statistically significant difference for FB (P <0.001). In regard to electrical activation of the SCM muscle, DB caused less activation than the BFRC (p<0.001) and SI exercises (P=0.001), whereas FB resulted in greater activity than that observed for BFRC (P=0.05) and SI (P=0.02)(Figure 3).

Comparison of scalene muscle electrical activity in both positions showed no significant differences for any of the investigated breathing exercises (P<0.001). When only the breathing exercises were compared, scalene activity was lower during DB than BFRC (P<0.001) and SI (P<0.001), with FB also resulting in less electrical activity than those recorded during BFRC (P<0.001) and SI (P=0.001). Greater scalene muscle activation was observed for BFRC in relation to the other exercises and was also significantly higher during SI (DB: P> 0.001; FB: P=0.02; BFRC: P=0.006). These results are presented in Figure 4.

Comparison of the different exercises in both positions demonstrated significantly lower scalene muscle activity during DB than in BFRC (P=0.01), and for FB in relation to BFRC (P=0.05). A significant difference was also observed in the sitting and 30° trunk inclination positions for BFRC and SI when compared to the other assessed breathing exercises (P>0.001).

Table 1. Sample characterization.

Variable	n=30
Age (years)	27.73 ±7.4
Height (m)	1.71±0.8
Weight (kg)	67.10±10.63
BMI (kg/m^2)	24.19±8.55
FEV_1/FVC	0.85±0.04
FEV_1(L)	3.80±0.73
%FEV_1	96.73±10.51
FVC(L)	4.44±0.91
%FVC	96.10±11.76

n: number; m: meters; Kg: kilograms; BMI: body mass index; FEV_1: Forced expiratory volume in the first second; FVC: Forced vital capacity; L: liters. Data are expressed as mean (standard deviation).

Discussion

The main results obtained in the present study were: 1) Diaphragmatic breathing caused the lowest activation of the respiratory muscles, compared to the other exercises or positions; 2) Among the studied respiratory muscles, the scalene muscle was most active during the four breathing exercises in both sitting and 30º trunk inclination positions; 3) Diaphragmatic mobility was greatest for 30º trunk inclination,

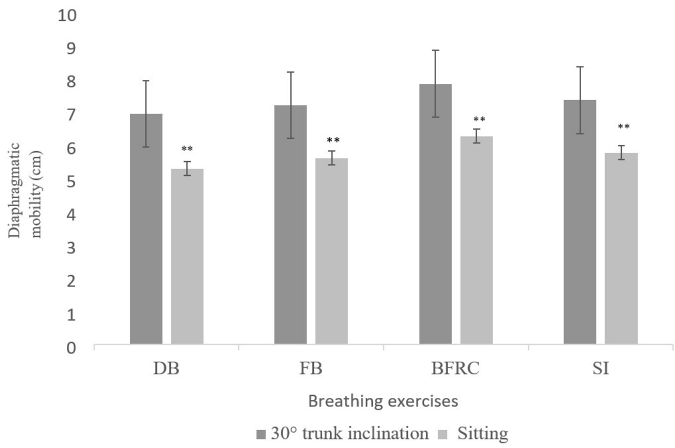

Figure 2. Comparison of diaphragmatic mobility values between the different breathing exercises in the two positions. **OBS: Values in cm; Breathing exercises; DB; FB; BFRC; SI; At 30° trunk inclination; Sitting.** DM: diaphragmatic mobility; DB: diaphragmatic breathing; FB: fractionated breathing; BFRC: breathing from functional residual capacity; SI: sniff inspiration. **p<0.05 statistical analysis of diaphragmatic mobility between the different positions.

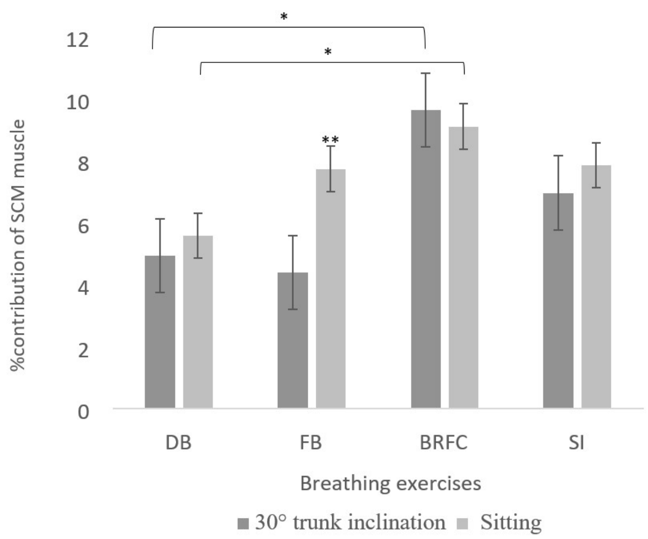

Figure 3. Comparison of the percentage contribution of SCM muscle electrical activity. **OBS: %contribution of SCM muscle electrical activity; Breathing exercises; DB; FB; BFRC; SI; At 30° trunk inclination; Sitting.** DM: diaphragmatic mobility; DB: diaphragmatic breathing; FB: fractionated breathing; BFRC: breathing from functional residual capacity; SI: sniff inspiration. **p<0.05 statistical difference between positions and **p<0.001 statistical analysis between exercises.

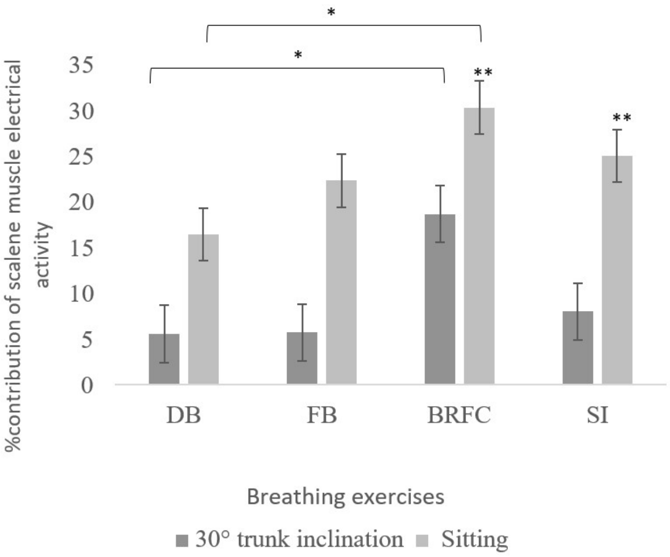

Figure 4. Comparison of the percentage contribution of scalene muscle electrical activity. **OBS: %contribution of scalene muscle electrical activity; Breathing exercises; DB; FB; BFRC; SI; At 30° trunk inclination; Sitting.** DM: diaphragmatic mobility; DB: diaphragmatic breathing; FB: fractionated breathing; BFRC: breathing from functional residual capacity; SI: sniff inspiration. **$p<0.05$ statistical difference between positions and **$p<0.001$ statistical analysis between exercises.

with the least use of the respiratory muscles; 4) Breathing from functional residual capacity mobilized the diaphragm most in relation to the other exercises, regardless of the position used.

Widely discussed in the literature, diaphragmatic breathing is associated with a variety of benefits and commonly used by physiotherapists in clinical practice[2,5]. Some authors[16] investigated the effects of DB on pulmonary ventilation, breathing pattern and DM in patients with COPD and found that DM was significantly lower among the patients when compared to healthy controls. DB significantly increased tidal volume and inspiratory flow and reduced the respiratory rate of both groups. In the present study, DB caused the least activation of the respiratory muscles. It is particularly relevant to know the muscle action during breathing exercises, as well as it is to know when they are better used.

A study[17] analyzed the electrical activity of respiratory muscles during diaphragmatic versus feedback breathing and observed less respiratory muscle use in DB. Another study[18] studied the oxygen consumption of respiratory muscles during DB using a gas analyzer and observed lower consumption during this exercise. The authors attributed this to the fact that the muscles of respiration are less used during DB. Both the aforementioned studies corroborate our findings.

With respect to muscles of respiration, the results obtained here demonstrated greater activation of the anterior scalene in all four exercises when compared to the sternocleidomastoid (SCM) muscle. A study[19] compared the length of the SCM and scalene muscles during forced inspiration using a CT scanner and reported greater scalene than SCM activation, corroborating our findings. In contrast, another study[20] found no difference between these muscles in an inspiratory muscle training protocol in healthy adults. A study[21] compared the influence of three breathing exercises (DB, flow and volume-oriented spirometry) on breathing pattern, thoracoabdominal motion and the electrical activity of scalene muscles. The exercises exhibited similar results, except for DB, which required the lowest scalene use.

Another finding of the present study was the difference in DM and respiratory muscle electrical activity between the two positions assessed. This is a relevant finding once physiotherapists use different positions during subjects' treatments to improve pulmonary ventilation. According to the literature, in dorsal decubitus, individuals typically exhibit a thoracoabdominal breathing pattern with predominantly abdominal movement. This is possibly due to the fact that the diaphragm is directly affected by the postural redistribution of visceral weight and the rib cage circumference and movement pattern change with position, causing greater diaphragmatic excursion[22-24].

In the sitting position, the abdominal muscles contract to keep the trunk stable and overcome gravitational forces, reducing abdominal movement in relation to other postures[25,26]. This reinforces our findings, whereby DM was greater during 30° trunk inclination than when participants were seated.

Studies that compare the effect of respiratory interventions in healthy adults on the electrical activity of the diaphragm and respiratory muscles (including the external intercostals, SCM and scalenes) in different positions (standing, sitting and forward leaning at 45º) have demonstrated lower external intercostal and SCM activity when leaning forward at 45º[6,27]. Another study[25] used ultrasound to study the influence of a position change from left to right lateral decubitus on DM during spontaneous breathing and found variations in DM with position shifts.

In regard to breathing exercises, although DB is widely disseminated in the literature, there are few studies on other exercises used by physiotherapists in clinical practice and investigated here. When properly executed, FB, SI and BFRC obtain similar total lung capacity values and are described as exercises that improve the expansion of lung bases[3,10].

The results of the present study indicate that although BFRC is the exercise that most mobilizes the diaphragm, it also results in the highest respiratory muscle activity. This is because execution requires greater intonation and the exercise itself is more vigorous, so that more activation of the respiratory muscles is expected, which may have influenced the results. Similar behavior was observed for SI, despite generating less activity than BFRC.

Although the limited age range of our sample is considered a limitation of this study, the inclusion of elderly people can interfere with the results due to sarcopenia. Another limitation was not performing the exercises in other positions, such as standing and supine. However, physiotherapists usually apply breathing exercises with the patient sitting or supine with a 30° inclination of the trunk.

We believe that our results answered the objectives of the study, demonstrating important characteristics in DM and respiratory muscle activity during the performance of different exercises. More importantly, the present study could clarify the muscle action during each exercise, contributing to a better prescription of these exercises in clinical practice. However, more research is needed, including in populations with respiratory disorders.

In conclusion, in clinical practice, diaphragmatic breathing proved to be the exercise that least used the respiratory muscles in these healthy subjects. However, the BFRC with a 30° trunk inclination is the most recommended exercise when the objective is the mobilization of the diaphragm. It is important to know the muscle action during breathing exercises for a better prescription.

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Conflict of interest

None.

References

1. Holland AE, Hill CJ, Jones AY, McDonald CF. Breathing exercises for chronic obstructive pulmonary disease. Cochrane Database Syst Rev. 2012;10:CD008250. http://dx.doi.org/10.1002/14651858.CD008250.pub2. PMid:23076942.
2. Vieira DSR, Mendes LPS, Elmiro NS, Velloso M, Britto RR, Parreira VF. Breathing exercises: influence on breathing pattern and thoracoabdominal motion in healthy subjects. Braz J Phys Ther. 2014;18(6):544-52. http://dx.doi.org/10.1590/bjpt-rbf.2014.0048. PMid:25590447.
3. Cuello GA, Masciantonio L, Cuello AF. Patrones respiratorios en distintas afecciones. Corde. 1982;3(3):48-60.
4. Kang J, Jeong I, Choi H. The effects of breathing exercise types on respiratory muscle activity and body function in patients with mild chronic obstructive pulmonary disease. J Phys Ther Sci. 2016;28(2):500-5. http://dx.doi.org/10.1589/jpts.28.500. PMid:27064889.
5. Morrow B, Brink J, Grace S, Pritchard L, Lupton-Smith A. The effect of positioning and diaphragmatic breathing exercises on respiratory muscle activity in people with chronic obstructive pulmonary disease. South African Journal of Physiotherapy. 2016;72(1):315. http://dx.doi.org/10.4102/sajp.v72i1.315. PMid:30135892.
6. Santos TV, Ruas G, Souza LAPS, Volpe MS. Influence of forward leaning and incentive spirometry on inspired volumes and inspiratory electromyographic activity during breathing exercises in healthy subjects. J Electromyogr Kinesiol. 2012;22(6):961-7. http://dx.doi.org/10.1016/j.jelekin.2012.05.001. PMid:22682605.
7. Boussuges A, Gole Y, Blanc P. Diaphragmatic motion studied by M-Mode ultrasonography: methods, reproducibility, and normal values. Chest. 2009;135(2):391-400. http://dx.doi.org/10.1378/chest.08-1541. PMid:19017880.
8. Testa A, Soldati G, Giannuzzi R, Berardi S, Portale G, Gentiloni Silveri N. Ultrasound M-Mode assessment of diaphragmatic kinetics by anterior transverse scanning in healthy subjects. Ultrasound Med Biol. 2011;37(1):44-52. http://dx.doi.org/10.1016/j.ultrasmedbio.2010.10.004. PMid:21144957.
9. Yamaguti WP, Claudino RC, Neto AP, Chammas MC, Gomes AC, Salge JM, et al. Diaphragmatic breathing training program improves abdominal motion during natural breathing in patients with chronic obstructive pulmonary disease: a randomized controlled trial. Arch Phys Med Rehabil. 2012;93(4):571-7. http://dx.doi.org/10.1016/j.apmr.2011.11.026. PMid:22464088.
10. Azeredo CAC. Fisioterapia respiratória moderna. 4. ed. Barueri: Editora Malone; 2002.
11. Chinali C, Busatto HG, Mortari DM, Rockenbach CWF, Leguisamo CP. Inspirometria de incentivo orientada a fluxo e padrões ventilatórios em pacientes submetidos a cirurgia abdominal alta. ConScientiae Saúde. 2009;8(2):203-10. http://dx.doi.org/10.5585/conssaude.v8i2.1587.
12. Andrade AD, Silva TNS, Vasconcelos H, Marcelino M, Rodrigues MG, Filho VCG, et al. Inspiratory muscular activation during threshold therapy in elderly healthy and patients with COPD. J Electromyogr Kinesiol. 2005;15(6):631-9. http://dx.doi.org/10.1016/j.jelekin.2005.06.002. PMid:16051499.
13. Chiti L, Biondi G, Morelot-panzini C, Raux M, Similowski T, Hug F. Scalene muscle activity during progressive inspiratory loading under pressure support ventilation in normal humans. Respir Physiol Neurobiol. 2008;164(3):441-8. http://dx.doi.org/10.1016/j.resp.2008.09.010. PMid:18952011.
14. Lunardi AC, Porras DC, Barbosa RC, Paisani DM, Silva CCM, Tanaka C, et al. Effect of volume-oriented versus flow-oriented incentive spirometry on chest wall volumes, inspiratory muscle activity, and thoracoabdominal synchrony in the elderly. Respir Care. 2014;59(3):420-6. http://dx.doi.org/10.4187/respcare.02665. PMid:23983269.
15. Jung J, Kim N. Relative activity of respiratory muscles during prescribed inspiratory muscle training in healthy people. J Phys Ther Sci. 2016;28(3):1046-9. http://dx.doi.org/10.1589/jpts.28.1046. PMid:27134409.
16. Fernandes M, Cukier A, Feltrim MIZ. Efficacy of diaphragmatic breathing in patients with chronic obstructive pulmonary disease. Chron Respir Dis. 2011;8(4):237-44. http://dx.doi.org/10.1177/1479972311424296. PMid:22094449.
17. Yong MS, Lee H, Lee Y. Effects of diaphragm breathing exercise and feedback breathing exercise on pulmonary function in healthy adults. J Phys Ther Sci. 2017;29(1):85-7. http://dx.doi.org/10.1589/jpts.29.85. PMid:28210046.
18. Ishii N, Tomita K, Suetake S, Okuno Y, Kawamura K, Takeshima R, et al. Oxygen cost of thoracic and diaphragmatic breathing during hyperventilation in healthy males. J Phys Ther Sci. 2018;30(2):238-41. http://dx.doi.org/10.1589/jpts.30.238. PMid:29545685.
19. Legrand A, Schneider E, Gevenois P, De Troyer A. Respiratory effects of the scalene and sternomastoid muscles in humans. J Appl Physiol. 2003;94(4):1467-72. http://dx.doi.org/10.1152/japplphysiol.00869.2002. PMid:12626472.
20. Ramsook AH, Molgat-Seon Y, Schaeffer MR, Wilkie SS, Camp PG, Reid WD, et al. Effects of inspiratory muscle training on respiratory muscle electromyography and dyspnea during exercise in healthy men. J Appl Physiol. 2017;122(5):1267-75. http://dx.doi.org/10.1152/japplphysiol.00046.2017. PMid:28255085.

21. Tomich GM, França DC, Diório ACM, Sampaio RF, Parreira VF. Breathing pattern, thoracoabdominal motion and muscular activity during three breathing exercises. Braz J Med Biol Res. 2007;40(10):1409-17. http://dx.doi.org/10.1590/S0100-879X2006005000165. PMid:17713643.

22. Paulin E, Yamaguti WPS, Chammas MC, Shibao S, Stelmach R, Cukier A, et al. Influence of diaphragmatic mobility on exercise tolerance and dyspnea in patients with COPD. Respir Med. 2007;101(10):2113-8. http://dx.doi.org/10.1016/j.rmed.2007.05.024. PMid:17644365.

23. Cavalcanti AG, Lima CS, Sá RB, Reinaux CM, Braz DS Jr, Teixeira AL, et al. Influence of posture on the ventilatory pattern and the thoraco-abdominal kinematics of patients with chronic obstructive pulmonary disease (COPD). Physiother Theory Pract. 2014;30(7):490-4. http://dx.doi.org/10.3109/09593985.2014.901458. PMid:24678754.

24. Contesini AM, Garcia A Jr, Caromano FA. Influência das variações da postura sentada na função respiratória: revisão de literatura. Fisioter Mov. 2011;24(4):757-67. http://dx.doi.org/10.1590/S0103-51502011000400021.

25. Yamaguti WPS, Paulin E, Shibao S, Kodaira S, Chammas MC, Carvalho CRF. Avaliação ultra-sonográfica da mobilidade do diafragma em diferentes posturas em sujeitos saudáveis. J Bras Pneumol. 2007;33(4):407-13. http://dx.doi.org/10.1590/S1806-37132007000400009. PMid:17982532.

26. Romei M, Mauro AL, D'Angelo MG, Turconi AC, Bresolin N, Pedotti A, et al. Effects of gender and posture on thoraco-abdominal kinematics during quiet breathing in healthy adults. Respir Physiol Neurobiol. 2010;172(3):184-91. http://dx.doi.org/10.1016/j.resp.2010.05.018. PMid:20510388.

27. Mesquita A, Tam C, Crasto C, Argel C, Melo D, Carvalho P, et al. Forward trunk lean with arm support affects the activity of accessory respiratory muscles and thoracoabdominal movement in healthy individuals. Hum Mov Sci. 2018;61(11):167-76. http://dx.doi.org/10.1016/j.humov.2018.07.011. PMid:30107366.

Author contributions

MRS: conceptualization of the study; writing, review, data collection, analysis; CCP: conceptualization of the study; analysis;

JC: data collection, analysis; DM: Supervision, analysis; EP: conceptualization of the study; writing, review supervision, analysis.

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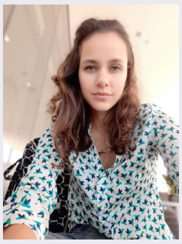

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