FLEX CEUs

COPD Manual Diaphragm Manipulation
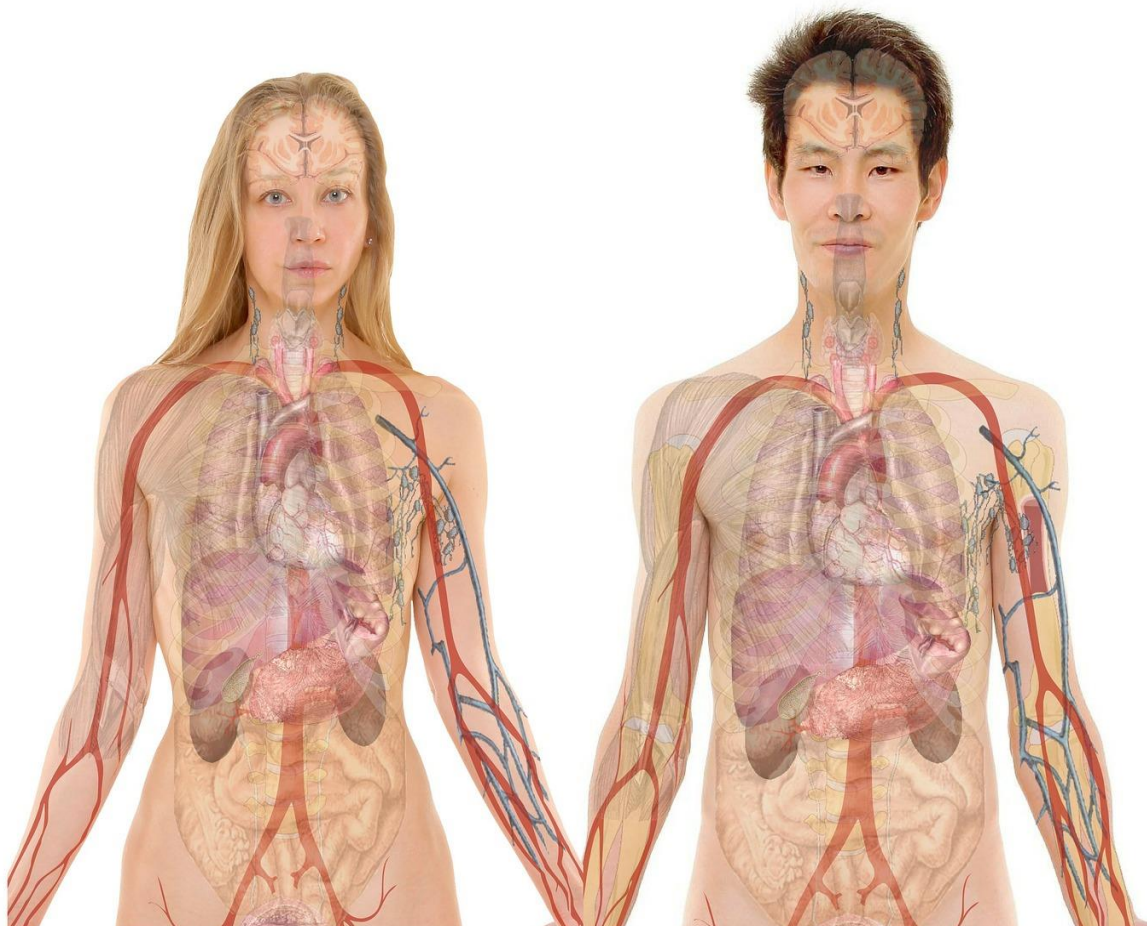
ABSTRACT

Questions: In people with chronic obstructive pulmonary disease, does the Manual Diaphragm Release Technique improve diaphragmatic mobility after a single treatment, or cumulatively? Does the technique also improve exercise capacity, maximal respiratory pressures, and kinematics of the chest wall and abdomen? **Design:** Randomised, controlled trial with concealed allocation, intention-to-treat analysis, and blinding of participants and assessors. **Participants:** Twenty adults aged over 60 years with clinically stable chronic obstructive pulmonary disease. **Intervention:** The experimental group received six treatments with the Manual Diaphragm Release Technique on non-consecutive days within a 2-week period. The control group received sham treatments following the same regimen. **Outcome measures:** The primary outcome was diaphragmatic mobility, which was analysed using ultrasonography. The secondary outcomes were: the 6-minute walk test; maximal respiratory pressures; and abdominal and chest wall kinematics measured by optoelectronic plethysmography. Outcomes were measured before and after the first and sixth treatments. **Results:** The Manual Diaphragm Release Technique significantly improved diaphragmatic mobility over the course of treatments, with a between-group difference in cumulative improvement of 18 mm (95% CI 8 to 28). The technique also significantly improved the 6-minute walk distance over the treatment course, with a between-group difference in improvement of 22 m (95% CI 11 to 32). Maximal expiratory pressure and sniff nasal inspiratory pressure both showed significant acute benefits from the technique during the first and sixth treatments, but no cumulative benefit. Inspiratory capacity estimated by optoelectronic plethysmography showed significant cumulative benefit of 330 ml (95% CI 100 to 560). The effects on other outcomes were non-significant or small. **Conclusion:** The Manual Diaphragm Release Technique improves diaphragmatic mobility, exercise capacity and inspiratory capacity in people with chronic obstructive pulmonary disease. This technique could be considered in the management of people with chronic obstructive pulmonary disease.´

Introduction

Chronic obstructive pulmonary disease (COPD) causes chronic inflammation of the airways and destruction of the lung parenchyma, which lead to structural changes and dynamic collapse in the small airways.[1] Its most striking feature is expiratory airflow limitation (ie, the ability to perform a complete exhalation is impaired, causing air trapping and lung hyperinflation).[1] The hyperinflation causes the diaphragm muscle fibres, which usually lie vertically in the zone of apposition, to become more transversely oriented. This makes the diaphragm's contraction less effective at raising and expanding the lower rib cage, and may even lead to a decrease in the transverse diameter of the

lower rib cage during inspiration.[2,3] The diaphragm then undergoes a reduction in the number of sarcomeres to restore its pressure-generating capacity; however, as a consequence, diaphragmatic mobility is reduced. The reduction of diaphragmatic motion is a major risk factor for increased mortality in people with COPD.[4]

The deterioration in airflow limitation with COPD progresses slowly, so most people who present with symptoms of COPD are elderly.[5] Thus, in addition to the parenchymal abnormalities, musculoskeletal changes inherent to the ageing process contribute to worsening symptoms in these people.[5] These musculoskeletal changes include increased chest wall stiffness due to the calcification of the costal cartilages and costovertebral joints.

Those changes hinder rib cage expansion, increase the work of breathing and reduce functional capacity.[6,7]

Given the interdependent relationship between the respiratory and musculoskeletal systems, various manual techniques have been proposed for the treatment of COPD symptoms. A common goal is increasing the mobility of the thoracic structures involved in respiratory mechanics.[8,9] The Manual Diaphragm Release Technique is an intervention intended to directly stretch the diaphragmatic muscle fibres, which is described in detail in textbooks.[10,11] Although this technique is widely used in clinical practice in some regions, it is believed that, to date, there are no quantitative studies or clinical trials evaluating the effects of this technique. The present study aimed to evaluate the effects of the Manual Diaphragm Release Technique on respiratory function of people with COPD.

Therefore, the research questions for this study were:

1. In people with COPD, does the Manual Diaphragm Release Technique improve diaphragmatic mobility after a single treatment, or cumulatively?
2. Does the technique also improve exercise capacity, maximal respiratory pressures, and kinematics of the abdomen and chest wall?

Method

Design

A single-centre, randomised, controlled trial was conducted in the Physiotherapy Department of the Universidade Federal de Pernambuco, Brazil, to determine the effects of the Manual Diaphragm Release Technique in adults with clinically stable COPD. Eligible participants were randomly allocated to one of two groups according to a random number table, which was held by a research associate who was not otherwise involved in the study. To ensure that allocations remained concealed until eligibility and enrolment were confirmed, the associate did not indicate to the therapist which group the participant would be allocated to until immediately before the intervention. Participants who were randomised to the experimental group received six treatments with the Manual Diaphragm Release Technique, while the control group received six sham treatments. Outcomes were measured before and after the first and sixth treatments. The researchers responsible for outcome measurement and data analysis were not permitted to know which group each participant belonged to. The protocol complied with the Declaration of Helsinki.

Participants, therapists and centre

The study's inclusion criteria were: ex-smokers; clinically stable (ie, no exacerbation in the previous 6 weeks); aged > 60 years; and post-bronchodilator measurements of forced expiratory volume in one second (FEV_1) < 80% predicted and $FEV_1 \leq 0.7$ of forced vital capacity (FVC).[1] The exclusion criteria were: other cardiopulmonary diseases, body mass index > 30 kg/m^2, previous thoracic surgery, lack of consent, and inability to understand the verbal commands necessary for the outcome assessments.

A portable spirometer[a] was used to assess FEV_1 and FVC according to American Thoracic Society/European Respiratory Society criteria,[12] which were interpreted against predicted values for the Brazilian population.[13] Age and gender were also recorded at baseline.

The interventions were applied by a single investigator, who had 8 years of experience as a physiotherapist and 3 years of experience specifically treating respiratory patients. Participants were recruited from the local university hospital. The study was conducted in a dedicated laboratory for cardiopulmonary physiotherapy research within the Physiotherapy Department.

Intervention

Participants in both groups received six treatments, separated by 1 to 2 days, during a 2-week period. The same therapist performed the intervention in both groups, in order to ensure similar application of the experimental and sham interventions.

Participants assigned to the experimental group received the Manual Diaphragm Release Technique, as shown in Figure 1. The participant lay supine with relaxed limbs. Positioned at the head of the participant, the therapist made manual contact with the pisiform, hypothenar region and the last three fingers bilaterally to the underside of the seventh to tenth rib costal cartilages, with the therapist's forearms aligned toward the participant's shoulders. In the inspiratory phase, the therapist gently pulled the points of contact with both hands in the direction of the head and slightly laterally, accompanying the elevation of the ribs. During exhalation, the therapist deepened contact toward the inner costal margin, maintaining resistance. In the subsequent respiratory cycles, the therapist progressively increased the depth of contact inside the costal margin. The manoeuvre was performed in two sets of 10 deep breaths, with a 1-minute interval between them.

In the control group, a sham protocol was applied. Manual contacts, duration, and positioning of the therapist and participant were the same as in the experimental group, but the therapist maintained only light touch with the same anatomical landmarks, without exerting pressure or traction.[14] This was intended to blind all participants about their group assignment during the study.

Outcome measures

The primary outcome was diaphragmatic mobility and the secondary outcomes were exercise capacity, maximal respiratory pressures, and abdominal and chest wall kinematics. Outcomes were measured in both groups on four occasions: before and immediately after the first treatment session (Pre 1 and Post 1) and immediately before and after the sixth treatment session (Pre 6 and Post 6). The only exception was exercise capacity, which was measured at Pre 1 and Pre 6.

Diaphragmatic mobility

To evaluate diaphragmatic mobility, a high-resolution ultra-sound[b] with a 3.5 MHz convex transducer was used according to the protocol suggested by Testa and colleagues.[15] Each participant was verbally instructed to perform an inspiratory capacity manoeuvre, and each curve corresponding to the diaphragmatic

Figure 1. Manual Diaphragm Release Technique. Source: Authors' own photo. With the participant lying supine, the therapist made manual contact (pisiform, hypothenar region and the last three fingers) with the underside of the costal cartilages of the seventh to tenth ribs. During the participant's inspiration, the therapist pulled gently in a cephalad direction accompanying the elevation movement of the ribs. During exhalation, the therapist deepened contact toward the inner costal margin. On subsequent breaths, the therapist sought to gain traction and smoothly deepen the contact. The manoeuvre was performed in two sets of 10 deep breaths, with a 1-minute interval between them.

displacement was measured (in mm) immediately after obtaining the images. The manoeuvres were repeated until five satisfactory images were obtained. The final value used in the analysis was the average of the three highest values that did not differ from each other by more than 10%. All ultrasound assessments were performed by the same assessor, aiming to reduce evaluation bias, as recommended by Testa and colleagues.[15] Figure 2 shows the measurement of the diaphragmatic displacement during an inspiratory capacity manoeuvre performed by one of the participants.

Exercise capacity

Exercise capacity was measured with the 6-minute walk test, which was performed in accordance with the American Thoracic Society criteria,[16] at Pre 1 and Pre 6.

Maximal respiratory pressures

Maximum inspiratory and expiratory pressures were obtained from the residual volume and total lung capacity, respectively, according to American Thoracic Society/European Respiratory Society criteria.[12] A portable digital manometer[c] was used to perform the evaluation. This manometer was also used to assess each participant's sniff nasal inspiratory pressure by placing the nasal plug into one nostril, without contralateral occlusion. Ten sniff manoeuvres were performed with maximal inspiratory effort (with 1 minute of rest between manoeuvres) and the greatest value achieved was used in the analysis.[17]

Optoelectronic plethysmography

Volumes of the chest wall and abdomen, and regional variations in those volumes with respiratory manoeuvres, were measured by optoelectronic plethysmography[d]. Eighty-nine reflective markers were placed on the participant's skin using a hypoallergenic adhesive over specific anatomical points of the chest wall and abdomen.[18] Changes in chest wall volumes were calculated, allowing acquisition of total chest wall volume (Vcw) and the division into three compartments: pulmonary rib cage (Vrcp), abdominal rib cage (Vrca) and abdomen (Vab).[19] These measurements were recorded during quiet breathing, a slow vital capacity manoeuvre and an inspiratory capacity manoeuvre. The optoelectronic plethysmography was performed with the participant sitting upright. After the pre-treatment assessment was complete, the markers on the participant's back were removed and their positions marked by a non-toxic pen, allowing their replacement in exactly the same location for the post-treatment assessment.
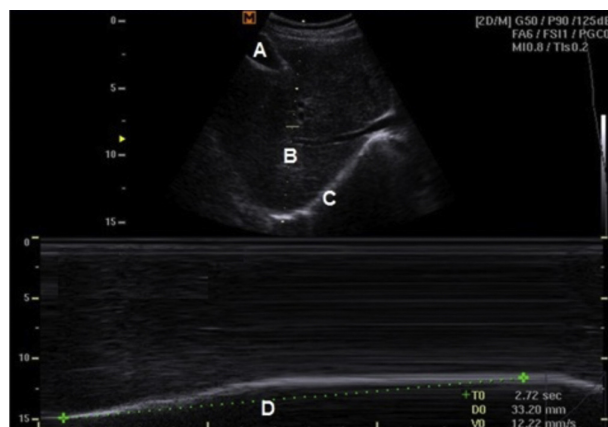
Figure 2. M-mode diaphragm ultrasonography. Source: Authors' own photo. A = gallbladder, B = reference beam for M-mode evaluation, C = diaphragm, D = positioning of markers for diaphragm displacement measurements, TO = inspiratory time (s), DO = diaphragmatic displacement (mm), VO = velocity of displacement (mm/s).

Data analysis

The immediate effect of the first application of the intervention for each participant was calculated by subtracting the Pre 1 value from the Post 1 value, with the average effect then determined as the mean between-group difference in change, with a 95% CI. The immediate effect of the sixth application was analysed the same way (ie, subtract Pre 6 from Post 6 for each participant and calculate the mean between-group difference and 95% CI). The cumulative effect of the repeated applications of the interventions was calculated by subtracting the Pre 1 value from the Pre 6 value for each participant, and again calculating the mean between-group difference in change with a 95% CI. Analysis was by intention to treat. Correlations between some variables were also assessed using linear regression analysis.

The sample size was calculated using commercial software[e] that accepts the anticipated data from each group to determine sample size. In the absence of published data to guide the anticipated values, it was decided a priori to calculate the sample size required for the primary outcome variable (ie, diaphragmatic mobility) with power ($1-\beta$) of 80%, an α of 5%, and data from the first seven experimental-group participants and seven control-group participants: 88 mm (SD 5) and 62 mm (SD 19), respectively. The sample size was estimated at 12 (six per group). To account for possible loss to follow-up, 20 participants were enrolled.

Results

Flow of participants through the study

Figure 3 shows the flow of participants through the study. The baseline characteristics of the participants are presented in Table 1 and in the first two columns of data in Tables 2 and 4. The groups were well balanced at baseline.

Compliance with the study protocol

One participant, who was allocated to the experimental group, completely withdrew from the study after the first assessment (Pre 1). All other participants received all scheduled treatments as allocated by the randomisation process and were analysed in those groups (ie, intention-to-treat analysis).

Effect of the Manual Diaphragm Release Technique

Diaphragmatic mobility

The diaphragmatic mobility data of both groups are presented in Figure 4 and Table 2. The average acute effect during the first treatment session was a between-group difference of 2 mm in favour of the experimental technique, but this was not statistically significant (95% CI –2 to 6). The average acute effect during the sixth treatment session was larger, with a between-group difference of 6 mm, which was statistically significant (95% CI 2 to 9). When the cumulative effect of the treatments was estimated by the change from before the first session to before the sixth session, the between-group difference was 18 mm in favour of the experimental technique, which was also statistically significant (95% CI 8 to 28). Individual participant data are presented in Table 3 on the eAddenda.

Exercise capacity

The experimental group showed a mean cumulative improvement on the 6-minute walk test of 15 m (SD 14) from before the first session to before the sixth session, whereas the control group deteriorated by a mean of 6 m (SD 6). This equated to a statistically significant between-group difference in change for the 6-minute walk distance in favour of the experimental group by 22 m (95% CI 11 to 32). Individual participant data are presented in Table 3 on the eAddenda.
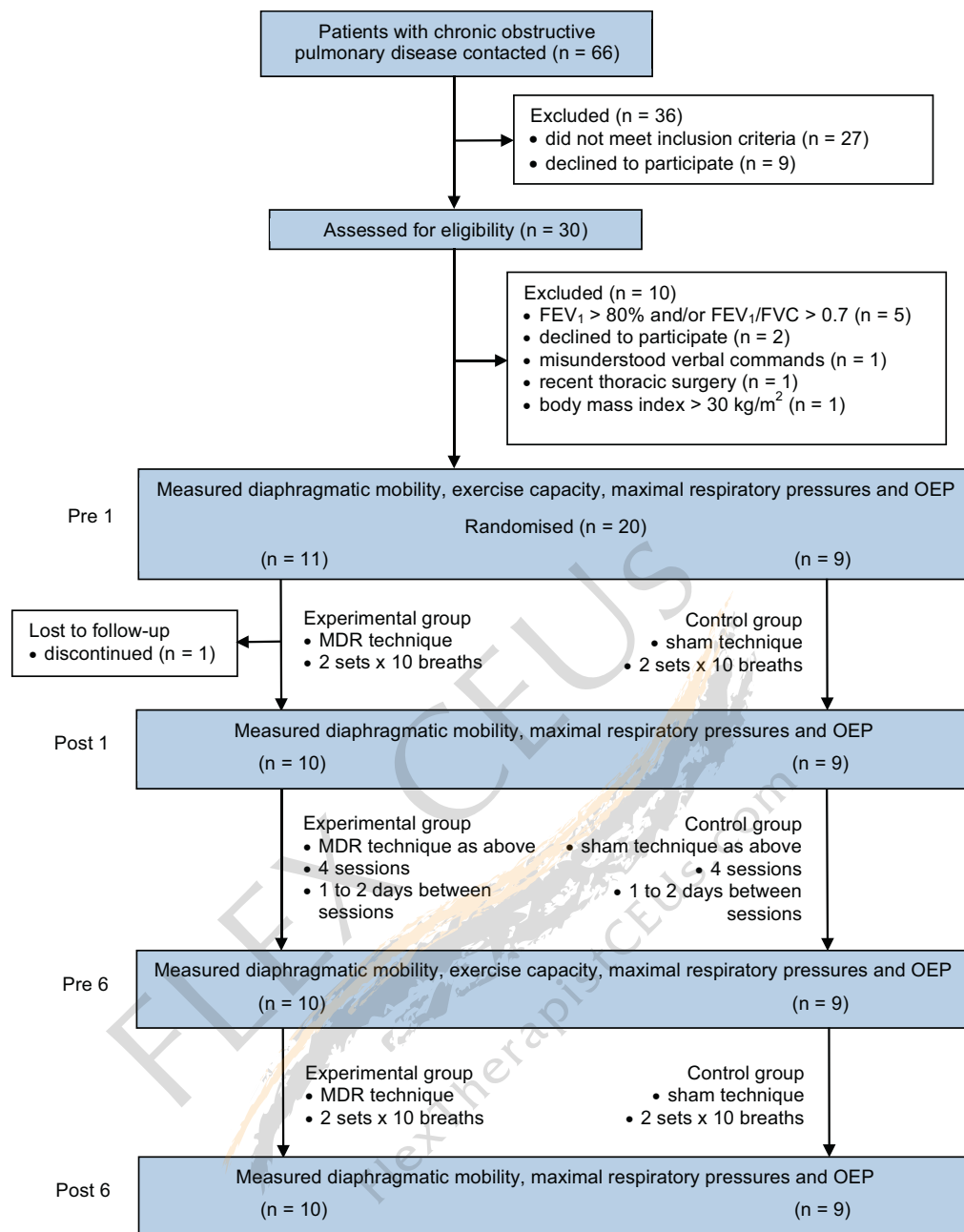
Figure 3. Design and flow of participants through the trial. MDR = Manual Diaphragmatic Release, OEP = optoelectronic plethysmography.

Maximal respiratory pressures

The mean between-group difference in change in maximal inspiratory pressure favoured the experimental group when analysed as change during the first session, change during the sixth session, and cumulative change over the course of treatments.

Characteristic	Exp (n = 9)	Con (n = 10)
Age (*yr*), mean (SD)	71 (6)	71 (5)
Gender, male:female	6:3	8:2
BMI (*kg/m²*), mean (SD)	26 (3)	24 (4)
FEV_1 (*%pred*), mean (SD)	36 (13)	33 (12)
FVC (*%pred*), mean (SD)	52 (17)	48 (9)
FEV_1/FVC (*%*), mean (SD)	53 (5)	49 (9)

Exp = experimental group, Con = control group.

However, none of these were statistically significant. Maximal expiratory pressure and sniff nasal inspiratory pressure both showed significant acute benefits of the Manual Diaphragm Release Technique during the first and sixth treatments. Neither measure showed a significant benefit when cumulative change was analysed. See Table 2, and Table 3 on the eAddenda for individual patient data.

Optoelectronic plethysmography

Optoelectronic plethysmographic estimates of vital capacity showed a significant benefit from the experimental intervention during the first treatment (mean between-group difference in change 295 ml, 95% CI 151 to 439) and again during the sixth treatment (249 ml, 95% CI 114 to 383). However, no significant cumulative benefit was observed, as shown in Figure 5. The estimates of inspiratory capacity showed a significant benefit from the experimental intervention during the first treatment (mean between-group difference in change 237 ml, 95% CI 95 to 380) but

Table 2

Mean (SD) for diaphragmatic mobility and maximal respiratory pressures for each group, mean (SD) difference within groups, and mean (95% CI) difference between groups for acute effect of the first session (Post 1 minus Pre 1), acute effect of the sixth session (Post 6 minus Pre 6) and cumulative effect (Pre 6 minus Pre 1).

Outcome	Groups								Difference within groups						Difference between groups		
	Pre 1		Post 1		Pre 6		Post 6		Post 1 minus Pre 1		Post 6 minus Pre 6		Pre 6 minus Pre 1		Post 1 minus Pre 1	Post 6 minus Pre 6	Pre 6 minus Pre 1
(units)	Exp	Con	Exp	Con	Exp	Con	Exp	Con	Exp	Con	Exp	Con	Exp	Con	Exp minus Con	Exp minus Con	Exp minus Con
	(n=10)	(n=9)	(n=10)	(n=9)	(n=10)	(n=9)	(n=10)	(n=9)									
Diaphragm mobility (mm)	71 (16)	68 (15)	73 (17)	69 (17)	82 (11)	61 (16)	87 (10)	61 (17)	3 (5)	0 (3)	5 (4)	−1 (3)	11 (11)	−7 (10)	2 (−2 to 6)	6 (2 to 9)	18 (8 to 28)
Maximal inspiratory pressure (cm H_2O)	64 (20)	64 (11)	67 (18)	59 (11)	64 (20)	61 (14)	69 (25)	61 (14)	3 (12)	−5 (5)	4 (6)	0 (2)	1 (7)	−3 (5)	8 (−1 to 17)	4 (0 to 9)	4 (−2 to 10)
Maximal expiratory pressure (cm H_2O)	98 (30)	99 (22)	101 (27)	89 (19)	104 (30)	107 (19)	105 (32)	102 (17)	2 (15)	−10 (7)	1 (6)	−5 (6)	6 (24)	8 (12)	13 (1 to 24)	6 (1 to 12)	−2 (−20 to 17)
Sniff nasal inspiratory pressure (cm H_2O)	48 (12)	53 (12)	56 (8)	50 (10)	51 (12)	49 (8)	59 (13)	48 (8)	7 (5)	−3 (5)	8 (6)	−1 (4)	3 (11)	−4 (9)	10 (5 to 16)	9 (4 to 14)	6 (−3 to 16)

Exp = experimental group, Con = control group, Pre 1 = before first session, Post 1 = after first session, Pre 6 = before sixth session, Post 6 = after sixth session.

Table 4

Mean (SD) for optoelectronic plethysmographic measures during quiet breathing for each group, mean (SD) difference within groups, and mean (95% CI) difference between groups for acute effect of first session (Post 1 minus Pre 1), acute effect of sixth session (Post 6 minus Pre 6) and cumulative effect (Pre 6 minus Pre 1).

| Outcome	Groups								Difference within group						Difference between groups		
	Pre 1		Post 1		Pre 6		Post 6		Post 1 minus Pre 1		Post 6 minus Pre 6		Pre 6 minus Pre 1		Post 1 minus Pre 1	Post 6 minus Pre 6	Pre 6 minus Pre 1
(units)	Exp	Con	Exp	Con	Exp	Con	Exp	Con	Exp	Con	Exp	Con	Exp	Con	Exp minus Con	Exp minus Con	Exp minus Con
	(n=10)	(n=9)	(n=10)	(n=9)	(n=10)	(n=9)	(n=10)	(n=9)									
Vcw (ml)	554 (151)	418 (69)	564 (158)	456 (101)	449 (168)	435 (126)	506 (157)	461 (124)	10 (94)	38 (73)	58 (48)	26 (104)	−105 (187)	17 (75)	−28 (−110 to 54)	31 (−46 to 108)	−122 (−263 to 19)
Vrcp (ml)	144 (66)	102 (41)	143 (79)	107 (42)	102 (65)	112 (42)	134 (66)	113 (52)	−2 (47)	5 (13)	32 (27)	1 (24)	−42 (45)	10 (17)	−7 (−40 to 27)	31 (6 to 56)	−52 (−86 to −18)
Vrca (ml)	67 (43)	48 (18)	66 (45)	50 (14)	41 (31)	65 (20)	49 (30)	59 (22)	−1 (15)	2 (22)	8 (13)	−7 (13)	−26 (46)	17 (31)	−3 (−21 to 16)	15 (2 to 27)	−43 (−86 to −5)
Vab (ml)	344 (92)	272 (102)	355 (99)	303 (138)	307 (102)	262 (129)	323 (97)	293 (140)	11 (62)	31 (72)	16 (32)	31 (89)	−37 (136)	−10 (62)	−21 (−85 to 44)	−15 (−79 to 48)	−27 (−131 to 77)

Exp = experimental group, Con = control group, Pre 1 = before first session, Pre 6 = before sixth session, Post 1 = after first session, Post 6 = after sixth session, Vab = volume abdomen, Vcw = total chest wall volume, Vrca = volume abdominal rib cage, Vrcp = volume pulmonary rib cage.
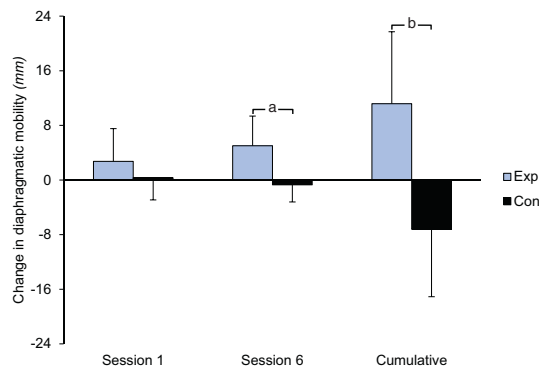
Figure 4. Change in diaphragmatic mobility in both groups during the treatment.
Exp = experimental group, Con = control group.
Session 1 = acute effect of first treatment session (Post 1 minus Pre 1). Session 6 = acute effect of sixth treatment session (Post 6 minus Pre 6). Cumulative = cumulative effect of first five sessions (Pre 6 minus Pre 1). Numerical data are presented in Table 2.
[a] mean difference in change 6 mm (95% CI 2 to 9).
[b] mean difference in change 18 mm (95% CI 8 to 28).
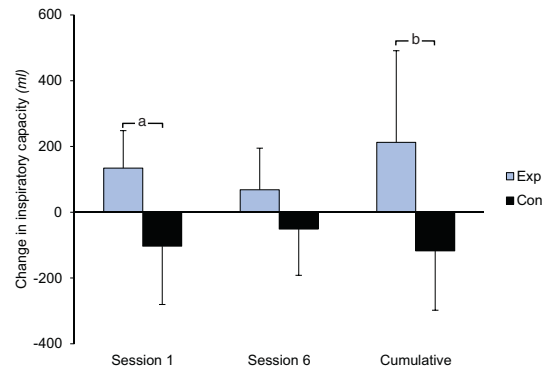
Figure 6. Change in inspiratory capacity in both groups during the treatment.
Exp = experimental group, Con = control group.
Session 1 = acute effect of first treatment session (Post 1 minus Pre 1). Session 6 = acute effect of sixth treatment session (Post 6 minus Pre 6). Cumulative = cumulative effect of first five sessions (Pre 6 minus Pre 1). Individual patient data are presented in Table 3.
[a] mean difference in change 237 ml (95% CI 95 to 380).
[b] mean difference in change 330 ml (95% CI 100 to 560).

not during the sixth treatment. Despite this, a significant cumulative benefit of 330 ml (95% CI 100 to 560) was observed, as shown in Figure 6. When compartmental volumes were analysed during the inspiratory capacity manoeuvre, there were no significant between-group differences in Vcw or Vab. Although Vrcp and Vrca each showed an acute benefit from the experimental intervention during the sixth session, they each also showed deterioration due to the experimental intervention when the cumulative effect was analysed, see the last two columns of Table 4. Although statistically significant, these could be clinically trivial effects because the 95% CI around the mean estimates do not exclude effects of 18 ml or smaller. When data from the first and sixth sessions were pooled, the acute improvements in diaphragmatic mobility and abdominal compartment volume during a session moderately correlated ($r = 0.45$), as shown in Figure 7. The individual participant data for all the optoelectronic plethysmographic outcomes are presented in Table 3 on the eAddenda.

Discussion

In the present study, the Manual Diaphragm Release Technique produced statistically significant improvements in diaphragmatic mobility, 6-minute walking distance and inspiratory capacity in

people with COPD. Immediate but non-cumulative benefits were also noted in vital capacity, maximum expiratory pressure and sniff nasal inspiratory pressure. The improvement in diaphragmatic mobility showed moderate correlation with abdominal volume during inspiratory capacity manoeuvres.

It is not possible to compare many of the present results with other published results because the evaluation methods used in the present study have not previously been applied to the experimental intervention. Indeed, the Manual Diaphragm Release Technique has undergone little research at all. The lack of studies on manual therapy in people with COPD was highlighted by Heneghan and colleagues in their systematic review,[20] which also revealed widespread non-concealment of allocation and lack of blinding in the studies that have been published. The use of these procedures in the present study is therefore one of its strengths.

The acute effects of the experimental intervention might seem to be an important outcome. However, the analysis of the cumulative effect may be more relevant because it reflects a sustained effect developing over the course of treatment. The lack of reference values for diaphragmatic mobility in a large population of healthy individuals weakens the comparison between the present study treatment outcomes against normative
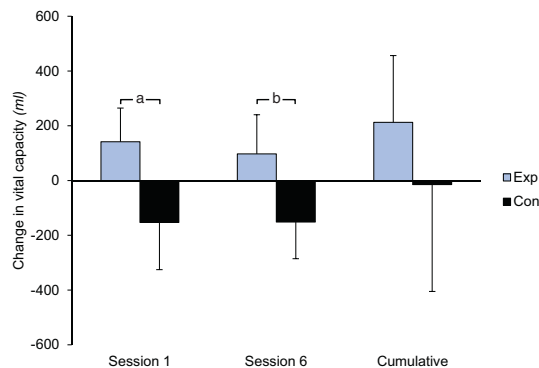
Figure 5. Change in vital capacity in both groups during the treatment.
Exp = experimental group, Con = control group.
Session 1 = acute effect of first treatment session (Post 1 minus Pre 1). Session 6 = acute effect of sixth treatment session (Post 6 minus Pre 6). Cumulative = cumulative effect of first five sessions (Pre 6 minus Pre 1). Individual patient data are presented in Table 3.
[a] mean difference in change 295 ml (95% CI 151 to 439).
[b] mean difference in change 249 ml (95% CI 114 to 383).
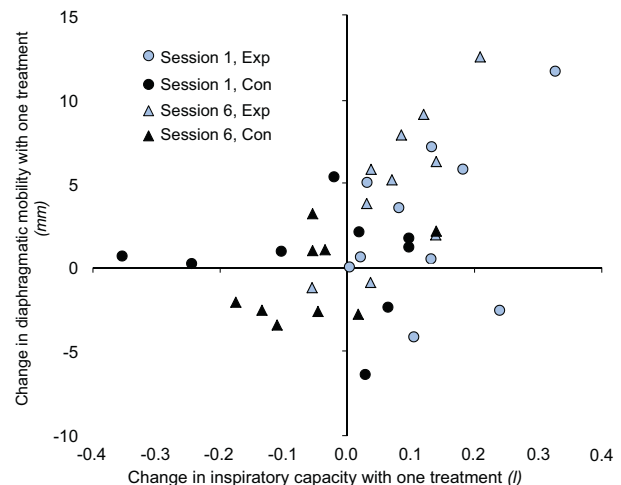
Figure 7. Relationship between changes in diaphragmatic mobility and inspiratory capacity within a single treatment (session 1 or session 6) in the trial.
Exp = experimental group, Con = control group.

data. However, if it is considered that the mean diaphragmatic mobility in 38 healthy individuals presented by Testa and colleagues was 79 mm (SD 14),[15] the cumulative effect of the repeated administration of the Manual Diaphragm Release Technique (ie, approximately 18 mm) seemed surprisingly to be enough to bring people with COPD close to the normal range of diaphragmatic mobility.

Given this beneficial effect on diaphragmatic mobility, it can be hypothesised that the manual action on the underside of the last four costal cartilages allows the traction of the lower rib cage in a cranial direction and that the manual compression of the tissues in the area of insertion of the anterior costal diaphragm fibres lengthens the diaphragm in its insertional zone. At the moment, this is only a speculative hypothesis, not supported by direct measurements. This hypothesis, however, could be tested in future studies, again by ultrasound, placing a larger probe at the midaxillary line in order to perform a quantitative evaluation of the diaphragm's zone of apposition, as previously suggested.[21]

According to Aliverti and colleagues,[21] in healthy people, accurate continuous measurements of abdominal volume variations allow estimation of instantaneous diaphragm displacement during quiet breathing, accounting for 89% of the variability of diaphragm displacement in the zone of apposition, whereas rib cage displacement accounts for less than 1%. More recently, Priori and colleagues[22] showed similar results in people with COPD, where change in Vab accounted on average for 76% of diaphragmatic displacement in the zone of apposition during quiet breathing in the seated position. The results of the present study, as shown in Figure 7, regarding the relationship between abdominal displacement (assessed by optoelectronic plethysmography) and diaphragmatic motion (assessed by ultrasound) during the inspiratory capacity manoeuvre confirm that these two measures of diaphragmatic displacement were correlated, although with a smaller regression coefficient. This might be because in the previous studies it was possible to record both measurements simultaneously, with diaphragmatic motion being assessed by placing the ultrasound probe on the lateral rib cage, thus allowing visibility of the markers. In the present study, diaphragmatic motion was assessed by placing the ultrasound probe on the anterior subcostal abdominal surface. It was therefore not possible to achieve simultaneous measurements and this probably led to the lower regression coefficient. Nevertheless, the significant effects of the intervention on diaphragmatic motion were corroborated by two independent methods of evaluation.

To date, no studies have evaluated changes in tidal volume by studying thoraco-abdominal kinematics in people with COPD after manual therapy techniques. Wilkens and colleagues observed that despite the structural remodelling of the diaphragm in this pathology, its ability to generate tidal volume remains preserved.[23] Despite this preserved capacity to generate not only tidal volume, but also tension,[24] of the diaphragm muscle in people with COPD, the compensatory adjustments that have been reported in the literature in terms of muscle remodelling[25] may not ensure normal diaphragmatic function in the presence of the persistent alterations in its geometry and coupling with the chest wall.[26] The present hypothesis was that direct intervention on the diaphragm and the chest wall, irrespective of residual diaphragm muscle ability to generate force, can partially reverse muscle remodelling, namely attenuating the shortening of the length of sarcomeres.

In people with obstructive lung disease, inspiratory capacity represents the operating limits for tidal volume expansion during the increased ventilation of exercise. Moreover, this variable can predict the peak symptom-limited oxygen uptake and is a determinant of exercise performance in these people.[27] The comparison of inspiratory capacity values between the present participants and healthy individuals would be biased by the physiopathology of this disease. Thus, the cumulative improvement of inspiratory capacity after the treatment (ie, approximately 330 ml) should be considered together with the functional gain in exercise capacity. The between-group difference in 6-minute walk distance in favour of the experimental group was slightly higher than the value presented as the smallest worthwhile effect of pulmonary rehabilitation in people with COPD.[28] According to MacNamara and colleagues, from the patient's perspective, an increase of 20 m on the 6-minute walk test can make the costs, risks and inconvenience of 8 weeks of pulmonary rehabilitation worthwhile.[28] Given that the Manual Diaphragm Release Technique is a more passive treatment administered in shorter sessions over 2 weeks, people with COPD would presumably consider the 22 m improvement worthwhile.

The cumulative analysis in this study demonstrated some substantial effects, but this may only represents effects maintained since the preceding treatment (ie, 1 or 2 days earlier). If the effects observed in this study were shown to be sustained for a longer period, a combination of manual therapy with pulmonary rehabilitation programs may be appropriate, as previously performed by Zanotti and colleagues.[29] In their study, the group that received rehabilitation with manual therapy showed significantly greater benefits in residual volume and 6-minute walk distance. Unfortunately, the authors did not describe the manual techniques used.[29]

The acute changes in maximal respiratory pressures may be related to a learning effect because no significant cumulative effect of the treatment on those variables (as determined by the change from Pre 1 to Pre 6) was found. Therefore, despite the increase in diaphragmatic mobility, the intervention did not appear to lead to any sustained improvement in the pressure generation of the muscle. This suggests that the proposed intervention has low influence over the diaphragm's contractile properties.

A limitation of the present study was that the study cohort was not sufficient to allow the effect of the experimental intervention to be analysed in different subgroups such as age or disease severity. However, the study cohort was representative of many people with COPD and subgroup analyses could be examined in a larger study.

Given that chest wall stiffness results from calcification of the costovertebral joints, intervertebral discs and costal cartilages in the elderly, causing the decline in vital capacity,[6] it might be hypothesised that the increased overall chest wall expansion observed in the experimental group, as seen in the increased vital capacity, is partly due to the effects imposed by this technique (ie, traction of the lower rib cage in a cranial direction). During repeated respiratory cycles, the technique may have promoted the mobilisation of rib cage joints and increased the range of motion of the entire rib cage. Nevertheless, it is difficult to comment about the effects of the proposed manual release technique on the chest wall as no studies are reported in the literature. Therefore, another hypothesis, to be confirmed in future studies, is that the technique acts both on diaphragm length and lower rib cage compliance.

In conclusion, the present study has demonstrated that the Manual Diaphragm Release Technique improves diaphragmatic mobility, inspiratory capacity and exercise capacity, suggesting that it should be considered in the management of people with COPD.

What is already known on this topic: People with chronic obstructive pulmonary disease (COPD) have impairment of expiratory airflow, lung hyperinflation, flattening of the diaphragm and reduced exercise capacity. Many people with COPD are older adults, so the natural reduction in chest wall mobility with age may exacerbate their respiratory limitation.
What this study adds: The Manual Diaphragm Release Technique applies manual pressure under the costal margin, with the intention of stretching the lower thoracic cage and the insertional fibres of the anterior diaphragm. Six sessions of this technique lead to cumulative improvements in diaphragmatic mobility, inspiratory capacity and exercise capacity.