Effect of Manual Therapy, Motor Control Exercise, and Inspiratory Muscle Training on Maximum Inspiratory Pressure and Postural Measures in Moderate Smokers: A Randomized Controlled Trial

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Abstract

Objective: The aim of this study is to assess whether adding manual therapy to motor control exercises protocol with inspiratory muscle training (IMT) (combined intervention) resulted in a greater effect than IMT alone in enhancing maximum inspiratory pressure (MIP) in the short term.
Methods: This was a single-blind, randomized, controlled trial. Fifty-one healthy moderate smokers were randomized into 2 groups: (1) IMT and (2) combined intervention. All participants received 8 individual sessions, 2 per week during a 4-week period. The primary outcome (MIP) and the secondary outcome (pulmonary function, forward head posture, and thoracic kyphosis) were recorded at baseline and after the treatments.
Results: There were differences between groups in change score for MIP (mean, 23.8; 95% confidence interval [CI]: 16.48-31.12), forward head posture (−1.57; 95% CI: –2.79 to –0.35), and thoracic kyphosis (–0.92; 95% CI: –1.74 to –0.1). The combined intervention revealed statistically significant differences for MIP (mean, –34; 95% CI: –39.12 to –28.88) and for postural measures (forward head posture 2.31; 95% CI: 1.45-3.16; thoracic kyphosis, 1.39; 95% CI: 0.8-1.97), whereas the IMT was only observed for MIP (mean, –10.2; 95% CI: –15.42 to –4.98). In addition, the intraclass correlation coefficient and minimal detectable change for MIP were 0.96; 95% CI: 0.93-0.97, and 17.70, respectively.
Conclusion: Inspiratory muscle training protocol combined with manual therapy and motor control exercise had greater effect in enhancing MIP than did IMT in isolation in moderate smokers in the short term. In addition, both groups experienced changes in MIP but not in lung function. (J Manipulative Physiol Ther 2018;41:372-382)
Key Indexing Terms: *Exercise; Physical Therapy Modalities; Posture; Reproducibility of Results; Breathing Exercises*

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Introduction

More than 20% of deaths worldwide are caused by respiratory diseases.[1] These include chronic obstructive pulmonary disease (COPD), which is expected to become the third leading cause of death in 2020.[1] Its prevalence is increasing because of exposure to risk factors such as tobacco. Chronic obstructive pulmonary disease occurs in 3% to 11% of smokers.[2]

The obstructive respiratory diseases are characterized by airflow limitation that involves changes in thorax geometry, inducing structural disturbances in the musculature.[3-5] These changes may unleash an alteration of muscle function and a decrease in strength and endurance.[3] In addition, some authors suggest an association between respiratory dysfunctions and postural disorders; an increase in thoracic kyphosis is especially associated with an increase in accessory inspiratory muscle activity.[4,5] The biomechanical model shows a rise in thoracic kyphosis and leads to greater head protraction.[6] This position is commonly referred to as "forward head posture."[6] Increasing forward head posture involves a reduction in the maximum voluntary ventilation and the maximum inspiratory pressure (MIP).[7] In addition, forward head posture leads to an inhibition of deep neck muscles and flexor and extensor groups. This can produce changes in the chest mechanics.[8,9] Consequently, maintaining correct thorax mobility is crucial for respiratory function because this allows complete excursion of the respiratory process.

Recent studies have reported improvements in inspiratory muscle strength in terms of MIP and peak inspiratory flow both in people with COPD[10-12] and in healthy people[13,14] after inspiratory muscle training (IMT) using threshold valves. These devices allow increasing inspiratory resistance progressively and represent a safe modality to improve inspiratory muscle.[15]

Furthermore, studies suggest that the application of manual therapy techniques that focus on the thoracic region (eg, mobilizations and manipulations) and exercise produce benefits in the range of motion, postural modifications,[16-19] and the volumes and capacities of the lungs in people with and without respiratory disease.[20-24] However, the literature regarding the benefits of manual therapy in lung volumes and capacities in COPD is lacking because it is difficult to determine the effectiveness of this therapy in this population.[25] Hence, this study could contribute to knowledge of manual therapy in respiratory disease.

The aim of this study was to assess whether manual therapy plus motor control exercises protocol combined with IMT results in a greater effect than IMT alone in enhancing MIP in the short term. The secondary objective was to determinate whether this combined intervention produces postural changes (eg, forward head posture and thoracic kyphosis) and modifications in lung function. It was hypothesized that an intervention that combines manual therapy techniques, exercises to stabilize muscles of the neck and shoulder girdle, and IMT would be more effective than IMT in isolation in improving MIP.

Methods

Study Design

This is a randomized, controlled, single-blinded, longitudinal trial. The study took place in the Center for Advanced Studies University La Salle (Madrid, Spain) according to the Consolidated Standards of Reporting Trials 2010 statement.[26] All of the procedures followed the Helsinki Declaration and were approved by the Ethics Committee of La Salle University Center for Advanced Studies, Madrid (PI-044). In addition, the trial was registered with the United States Clinical Trials Registry (registration number: NCT02514161).

Randomization

The sample was classified in 2 groups: (1) IMT group and (2) combined intervention group (combination of IMT with manual therapy and motor control exercise techniques). An external person assigned each participant to 1 of the 2 treatment groups according to a simple random allocation method, assisted by GraphPad Software (La Jolla, California). To ensure blinding, the assessor was unaware of the assigned group; all participants were instructed not to speak about the intervention with the evaluators.

Participants

The participants were recruited on the university campus by email and social networks from June to November 2015. All participants were 18 to 60 years old and had a pack per year index of ≥5 (moderate smoking index). In addition, all participants read and signed the informed consent form. This study excluded those who presented a cardiorespiratory pathology, systematic or metabolic disease (eg, rheumatoid arthritis or cancer), history of thoracic surgery, vertebral fracture, or osteoarticular disorders of the spine and thoracic area (eg, pectus excavatum, scoliosis) and those who had any contraindication to the treatment techniques (eg, osteoporosis).

Intervention

All participants completed 8 sessions during 4 weeks, twice per week. Every session was individual; a time interval of at least 72 hours was used between sessions. Participants who did not complete 7 sessions were withdrawn from the study.

Inspiratory Muscle Training Group. The participants performed IMT for 30 minutes, 2 days per week, for 4 weeks using POWERbreathe Medic Classic (Gaiam Ltd, Southam, Warwickshire, United Kingdom) (Fig 1). The training was done individually in a lateral position under the supervision of the same physiotherapist. This was distributed in 5 blocks of 5 repetitions with 30 seconds of rest. The training loads were increased: first week, 30% MIP; second week, 40% MIP; third week, 50% MIP; and the fourth week, 60% MIP. The training started with 30% loading because it is considered the minimum intensity for IMT in people with COPD.[11,27] In addition, this group carried out a domiciliary breathing exercises protocol for a minimum of 4 days per week, at least once a day. Appendix 1 describes the exercise intervention (available online only).

Combined Intervention. This group followed the same IMT protocol described previously in combination with manual therapy and motor control exercise. These exercises were introduced progressively during the first week in 50- to 60-minute sessions (30 minutes for IMT and 20-30 minutes for

Fig 1. *Inspiratory muscle training using the threshold device in lateral position.*

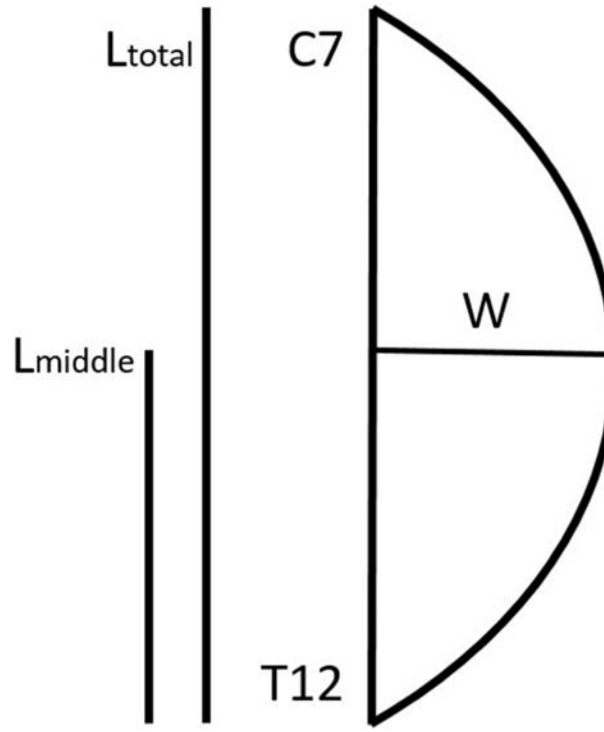

Fig 2. *The flexicurve kyphosis index was calculated using the flexicurve tracing, represented by the curve from C7 to T12 (L_{total}). The apex kyphosis height (W) is divided by the length of the entire thoracic curve (L_{total}) and then multiplied by 100 ($W \div L_{total} \times 100$).*

manual therapy or motor control exercise). The manual therapy techniques were applied in the thorax and cervical area to improve the mobility of these regions, and motor control exercises were used to improve the strength and endurance of cervical and scapular stabilizing muscles. The program was developed by the same physiotherapist. In addition, this group performed the motor control exercises program at home for a minimum of 4 days per week, at least once a day. Appendix 2 describes every technique (available online only).

Baseline Variables

To ensure that the 2 groups had similar characteristics at the beginning of the study, the following variables were evaluated: (1) smoking index and (2) physical activity level.

Smoking Index. This variable was considered to be a dependent variable. The pack per year index is a smoking load tool of lifetime tobacco exposure. A pack per year index is defined as 20 cigarettes smoked every day for 1 year. It was calculated using the formula: (number of smoked cigarettes per day × number of years smoking) / 20.[28] The levels of the smoking index were mild (<5 packs), moderate (5-15 packs) or strong (>16 packs).

Physical Activity Level. The level of physical activity was measured by the Spanish short version of the International Physical Activity Questionnaire.[29] It is a valid and reliable instrument used in different countries.[30] This consisted of 7 items in 4 domains: vigorous-intensity activities, moderate-intensity activities, walks, and sitting time in the last 7 days. The physical activity index was measured in metabolic equivalent, and the classification was low, moderate, or high.

Outcome Measures

Primary Outcomes: MIP. The MIP was measured by the POWERbreath Kinetic KH1 device (HaB International Ltd, Southam, United Kingdom), validated by Langer et al.[31] The device produces an inspiratory charge through an electronic controlled valve that provides a variable resistance. The maneuver was performed in a sitting position in triplicate and registered the highest value according to the American Thoracic Society's statement.[32]

Secondary Outcomes: Pulmonary Function. Lung functions were tested by simple forced spirometry using a portable spirometer (EasyOne Bluetooth, ndd Medical Technologies, Inc, Andover, Massachusetts) following the American Thoracic Society's criteria.[33] The test was repeated at least 3 times to a maximum of 8 times, and the best values were registered. The measurements included were forced vital capacity (FVC), forced expiratory volume in the first second (FEV_1), and peak expiratory flow (PEF). The reliability of this instrument was reported by Burton et al.[34]

Forward head posture was measured with the CROM device (Performance Attainment Associates, Roseville, Minnesota) using a standardized process. The patient was seated, and a reference point in front of the patient was used.[35]

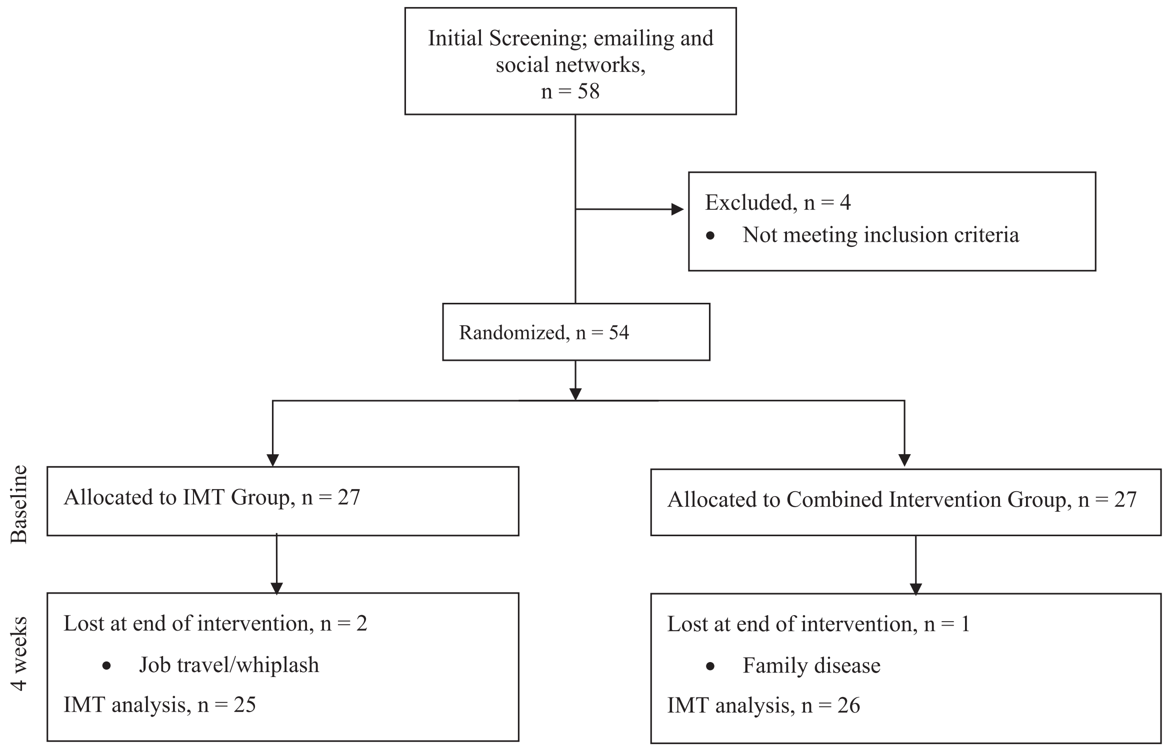

Fig 3. *Flow diagram for experimental procedures. The Combined Intervention Group received inspiratory muscle training combined with a program of manual therapy and motor control therapeutic exercise.* IMT, *inspiratory muscle training.*

The evaluator made 3 measurements, and the participants were asked to stand up and sit down before each one. The CROM device is a reliable instrument,[35] and it presents a minimal detectable change (MDC) of 1.30 cm for asymptomatic participants.[36]

The measurement of thoracic kyphosis was done using the flexicurve device (Staedtler Mars Inc, Nurnberg, Germany), which is a flexible ruler that shapes the back.[37] This device is a valid and reliable instrument to measure the thoracic kyphosis.[38] The spine model was shaped in a standing position from the C7 to the L1 spinal process. Finally, the curve was drawn on paper, indicating C7 and T1. The flexicurve index was obtained through the relation between the length and width of the thorax, by the following formula: (length / width × 100) (Fig 2).

Sample-Size Determination

The sample size was calculated with G*Power 3.1.7 for Windows (G*Power: University of Dusseldorf, Dusseldorf, Germany).[39] It was considered a power calculation to detect between-group differences in the MIP (primary outcome). A multiple comparisons analysis was used to detect mean difference between groups because it was the main interest factor. An effect size of 0.9 (large) was determined based on a pilot study with a sample of 15 participants (8 from the IMT group and 7 from the combined intervention group). With a power of 0.90 and an α error of 0.05, a sample size of 44 participants (22 per group) was obtained. In addition, because of the longitudinal nature of the study, a dropout rate of 20% was estimated. Finally, it was concluded that at least 53 participants were required.

Data Analysis

The Statistical Package for Social Sciences version 21 (IBM Corp, Armonk, New York) software was used for statistical analysis. The Kolmogorov-Smirnov test showed a normal distribution of the data ($P > .05$), except for anthropometric characteristics and lifestyle variables (smoking and physical activity). Descriptive statistics were used to summarize data for continuous variables and are presented as means ± standard deviation (SD) and 95% confidence intervals, whereas the categorical variables are presented as an absolute number or relative frequency percentage. For continuous parametric data, a separate 2 × 2 mixed-models analysis of variance (ANOVA) was used to examine the effects of interventions on MIP, pulmonary function (FEV_1, FVC, FEV_1/FVC, and PEF), forward head posture, and thoracic kyphosis. The factors analyzed were group (IMT group, combined intervention group) and time (preintervention and postintervention). The hypothesis of

Table 1. *Baseline Characteristics of Participants*

	IMT (n = 25)	Combined Intervention (n = 26)
Age, y [a]	28.9 ± 12.1	32.8 ± 14.1
Sex, male:female	14:56	13:50
Body mass index, kg/m^2 [a]	22.6 ± 3.3	24.9 ± 4.9
Smoking index, p/y [a]	11.7 ± 12.8	14.1 ± 12.9
Physical activity level (IPAQ-SF)		
Low, n (%)	5 (20)	7 (26.9)
Moderate, n (%)	13 (52)	13 (50)
High, n (%)	7 (28)	6 (23.1)
Total score, MET (min/work) [a]	2218.6 ± 1964.4	2240 ± 2285

IMT, inspiratory muscle training; *IPAQ-SF,* International Physical Activity Questionnaire-Short Form; *MET,* metabolic equivalent; *SD,* standard deviation.

[a] Values are mean ± SD.

interest was the group × time interaction. Partial eta-squared (η^2_p) was calculated as a measure of effect size (strength of association) for each main effect and interaction in the ANOVAs with 0.01 to 0.059 representing a small effect, 0.06 to 0.139 representing a medium effect, and >0.14 representing a large effect.[40] Post hoc analysis with Bonferroni corrections was performed in the case of significant ANOVA findings. In addition, when significant group × time interactions were found, independent *t* tests were used to determine between-group differences in change score. The within-group and between-group effect sizes were calculated using Cohen's d coefficient; effect sizes of 0.2 to 0.49 were considered small, 0.5 to 0.79 were considered moderate, and >0.8 were considered large.[41] A value of $P < .05$ was considered to be statistically significant.

For MIP and pulmonary function variables, the intrarater reliability was evaluated using the intraclass correlation coefficient (ICC). Reliability levels were defined based on the following classification: good reliability, ICC ≥0.75; moderate reliability, ICC ≥0.50 and <0.75; and poor reliability, <0.50.[42] Standard error of measurement (SEM) was calculated as SD × $\sqrt{1-\text{ICC}}$, where SD is the SD of values from all participants, and ICC is the reliability coefficient.[43] The MDC_{95} expresses the minimal change required to be 95% confident that the observed change between the 2 measures reflects real change and is not measurement error as computed as SEM × $\sqrt{2}$ × 1.96.[44]

In addition, to compare the change in MIP (primary outcome) between the 2 interventions, the risk ratio (relative risk), absolute risk reduction, and number needed to treat to observe an event[45] and, in this case, to find a clinically important improvement were calculated. To calculate these measures, the variable MIP was dichotomized based on the moderate smokers who obtained a percentage change score of 30% or more improvement; some authors consider this percentage of improvement to be clinically important.[46]

Results

A total of 58 participants were screened from June to November 2015, of whom 54 were included because 4 did not meet the required level of smoking. During the protocol, 3 participants discontinued the intervention, mainly for practical reasons (job travel, whiplash, family disease); therefore, they were not included (Fig 3). Baseline demographic characteristics of the 51 participants (IMT, n = 25; combined intervention, n = 26) are depicted in Table 1, and lung function is shown in Table 2. No significant differences existed between groups concerning baseline measurements ($P > .05$). No adverse effects were reported in any of the groups.

Statistically significant differences were found in ANOVA for the group × time interaction for MIP (F = 42.73, $P < .001$, $\eta^2_p = 0.47$), forward head posture (F = 6.72, $P = .013$, $\eta^2_p = 0.12$), and thoracic kyphosis (F = 5.03, $P = .030$, $\eta^2_p = 0.10$). Statistically significant differences between groups in change score at the end of intervention were observed for MIP, forward head posture, and thoracic kyphosis. The greatest effect size between groups in change score was observed for MIP (d = 1.84). The combined intervention group showed statistically significant differences between baseline and postintervention measures for all of these variables, whereas the IMT intervention was only observed for MIP. The greatest effect sizes were found in the combined intervention in all measures and resulted in the largest effect in the MIP ($d = -1.02$). The descriptive data and post hoc results are presented in Table 3.

In addition, both groups presented MIP values less than 80% predicted (ie, normal) at baseline. These values increased more than 10% postintervention. The combined intervention yielded a superior relative increase in MIP (cm H_2O) versus the IMT group (45% and 13%, respectively). No significant changes were found in FVC, FEV_1, or PEF in either group (Table 2). However, the combined intervention showed a small increase in PEF (12%, % change in liters). Percentages of change and predicted values are presented in Table 2.

The ICC values were good for the functional pulmonary parameters (ICC range = 0.90-0.96); the largest ICC was found for MIP. The ICCs and associated 95% confidence intervals, SEMs, and MDC_{95} between each evaluator's trials are presented in Table 4.

Table 2. *Within-Group Change Score for Functional Pulmonary Parameters*

	IMT (n = 25)			Combined Intervention (n = 26)		
	Preintervention	Postintervention	Within-Group Change Score [a]	Preintervention	Postintervention	Within-Group Change Score [a]
MIP						
cm H_2O	78.36 ± 33.6	88.56 ± 34.47	–10.2 (–15.42 to –4.98) [b]; 13.02	75.08 ± 32.63	109.08 ± 33.73	–34 (–39.12 to –28.88) [b]; 45.29
% pred	79.35 ± 26.69	90.11 ± 26.6		75.61 ± 27.65	110.61 ± 31.69	
FVC						
L	3.88 ± 0.9	3.93 ± 0.87	–0.05 (–0.22 to 0.12); 1.28	4 ± 1.15	4.05 ± 1.07	–0.05 (–0.22 to 0.12); 1.25
% pred	81.96 ± 13.21	83.07 ± 12.55		86.44 ± 11.88	87.73 ± 10.39	
FEV_1						
L	3.2 ± 0.73	3.3 ± 0.73	–0.09 (–0.2 to 0.02); 3.12	3.36 ± 1.02	3.38 ± 1.01	–0.03 (–0.13 to 0.08); 0.59
% pred	84.41 ± 13.02	86.82 ± 12.66		90.82 ± 13.50	91.59 ± 13.25	
FEV_1/FVC						
% pred	82.92 ± 7.91	83.12 ± 6.59	–0.2 (–2.85 to 2.45); 0.24	82.35 ± 6.16	82.69 ± 6.11	–0.35 (–2.95 to 2.26); 0.41
PEF						
L	7.18 ± 2.61	7.54 ± 2.47	–0.36 (–0.89 to 0.18); 5.01	7.19 ± 2.11	8.08 ± 2.31	–0.89 (–1.41 to –0.36); 12.37
% pred	84.93 ± 21.79	88.57 ± 18.91		86.23 ± 15.90	96.41 ± 13.77	

FEV_1, force expiratory volume first second; *FVC*, force vital capacity; *IMT*, inspiratory muscle training; *L*, liters; *MIP,* maximal inspiratory pressure; *PEF,* peak expiratory flow; *% pred*, percentage of predicted value; *SD,* standard deviation.
Note: Values are mean ± SD unless otherwise indicated.
[a] Values are mean difference (95% confidence interval); % change.
[b] Statistically significant differences $P < .01$.

The likelihood of obtaining a 30% or more change score in MIP improvement with the combined intervention compared with IMT group had a risk ratio of 6.41 (2.17-18.92), absolute risk of reduction 64.92% (44.32%-85.53%), and number needed to treat of 1.5 (1.2-2.3). The percentage of moderate smokers for each intervention group that showed a change score ≥30% in the MIP variable is presented in Figure 4.

Discussion

To our knowledge, no previous studies have analyzed the effect of this combined intervention on MIP, pulmonary function, and postural measures (forward head posture and thoracic kyphosis). This is also the first study to provide the MDC values for MIP measurements.

The findings of this study demonstrated that the combination of both therapies was more effective than the IMT protocol applied in isolation to improve MIP and postural measures. Both interventions improved MIP, with the combined intervention being more effective. In fact, only the combined intervention exceeded the MDC; this indicated that the change is real. In addition, the combined intervention showed a large effect size that could be clinically important.[47,48] This last hypothesis is supported by the results observed in this study for the risk ratio. According to these results, moderate smokers who received the combined intervention had a 6.41 times greater clinically important improvement (30% change score)[46] in MIP compared to moderate smokers who received IMT. Hence, for each participant who obtained a clinically important difference in the IMT group, 7 participants in the combined intervention group did so. In fact, the application of the combined intervention increased the likelihood of having a clinically important change by 64.92% compared with the application of IMT in isolation. Furthermore, it is necessary to treat 2 participants using the combined intervention to avoid 1 case of not clinically important improvement in MIP (number needed to treat = 1.5); this means that about 1 of every 2 moderate smokers will benefit from the combined intervention. With respect to the incremental cost-effectiveness ratio, the combined intervention was twice as costly as IMT in isolation because the

Table 3. *Outcome Data for Maximal Inspiratory Pressure, Forward Head Posture, and Thoracic Kyphosis*

	Preintervention	Postintervention	Within-Group Change Score [a]	Between-Group Difference in Change Score [a]
MIP, cm H_2O				23.8 (16.48-31.12) [b]; d = 1.84
IMT	78.36 ± 33.6	88.56 ± 34.47	–10.2 (–15.42 to –4.98) [b]; d = –0.30	
Combined intervention	75.08 ± 32.63	109.08 ± 33.73	–34 (–39.12 to –28.88) [b]; d = –1.02	
Between-group difference [b]		–20.52 (–39.71 to –1.33) [b]; d = –0.60		
Forward head posture, cm				–1.57 (–2.79 to –0.35) [c]; d = –0.73
IMT	19.23 ± 2.73	18.49 ± 2.34	0.74 (–0.13 to 1.61); d = 0.29	
Combined intervention	19.35 ± 3.02	17.04 ± 2.53	2.31 (1.45-3.16) [c]; d = 0.83	
Between-group difference [c]		1.45 (0.08-2.82) [c]; d = 0.60		
Thoracic kyphosis, index (%)				–0.92 (–1.74 to –0.1) [c]; d = –0.63
IMT	8.94 ± 2.33	8.47 ± 2.35	0.47 (–0.12 to 1.05); d = 0.20	
Combined intervention	10.05 ± 1.66	8.67 ± 1.51	1.39 (0.8-1.97); [b] d = 0.87	
Between–group difference [c]		–0.2 (–1.32 to 0.93); d = –0.10		

IMT, inspiratory muscle training; *MIP,* maximal inspiratory pressure; *SD,* standard deviation.
Note: Values are mean ± SD unless otherwise indicated.
[a] Values are mean (95% confidence interval); Cohen's d effect size.
[b] Statistically significant differences $P < .01$.
[c] Statistically significant differences $P < .05$.

Table 4. *Intrarater Reliability for Maximal Inspiratory Pressure and Pulmonary Function Measurements*

	$ICC_{1,2}$	95% CI for ICC	SEM	MDC_{95}
MIP, cm H_2O	0.96	0.93-0.97	6.38	17.70
FVC, L	0.92	0.88-0.95	0.29	0.81
FEV_1, L	0.95	0.92-0.97	0.20	0.56
PEF, L	0.90	0.84-0.93	0.82	2.27

CI, confidence interval; *FEV_1*, force expiratory volume first second; *FVC*, force vital capacity; *ICC*, intraclass correlation coefficient; *MDC_{95}*, minimal detectable change at the 95% confidence level; *MIP*, maximal inspiratory pressure; *PEF,* peak expiratory flow; *SEM*, standard error of the measurement.

duration of each combined intervention was 60 minutes, whereas IMT in isolation was 30 minutes; this means that incremental cost-effectiveness ratio = number needed to treat × 2 × cost of IMT in isolation. Taking into account that usually the time of a physiotherapy session is 60 minutes, and supposing that this session has a cost of approximately $40 (30 minutes costs $20),[49,50] the incremental cost-effectiveness ratio (concrete cost-benefit analysis) for applying the combined intervention is $240; it could be interesting to adopt the combined intervention considering the cost-benefit relationship of this intervention. Thus, the authors consider that the combination intervention is more

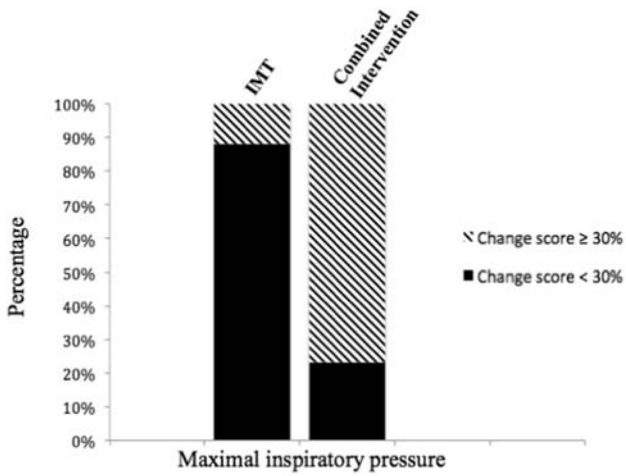

Fig 4. *Percentage of moderate smokers classified according to the percentage of change score considered as clinically relevant (30%) for maximal inspiratory pressure.* IMT, *inspiratory muscle training.*

effective than the IMT in isolation to improve MIP in both statistical and clinical significance.

On the other hand, a wide range of evidence indicates that IMT improves MIP values in people with obstructive respiratory diseases.[10,11,51,52] This improvement could be because IMT increases the neuromuscular coordination of the inspiratory muscles[53] and produces diaphragm hypertrophy generated by repeated training.[54,55] In 2011, a meta-analysis conducted by Gosselink et al[11] reported that the implementation of IMT in isolation produces an average change in MIP of 13 cm H_2O in people with COPD. This increase is very similar to the change obtained in the present study (10.2 cm H_2O). Recent studies observed that IMT increased the MIP by 9.61 to 18 cm H_2O.[10,51] In addition, IMT can increase MIP in other obstructive diseases such as asthma,[52] showing an average improvement of 13.34 cm H_2O. Most of these results are slightly higher than those obtained in this study, but this superiority could be because these studies were conducted in people with respiratory disease who may have more scope for improvement. In addition, time interventions in most of these studies were superior to that in the present study (more than 4 weeks). Thus, future studies are needed to evaluate the optimal duration of the intervention.

The hypothesis was confirmed because the combined intervention was more effective. Increased joint mobility, decreased muscle hypertonia, and postural changes (forward head posture and thoracic kyphosis) are some of the effects attributed to manual therapy and exercise.[16-19] Postural disorders, including forward head posture, may increase thoracic kyphosis.[56] This decreases thorax mobility, and respiratory function deteriorates.[8,57] Hence, further benefits resulting from the combined intervention might be explained by postural changes and the close relationship between the musculoskeletal system and the respiratory system.[4,5,7,58,59] To the best of our knowledge, this is the first study to evaluate the effect of manual therapy on MIP, so it is impossible to compare these results to other studies. Future studies are needed.

No lung function changes were observed in any group. There are few studies related to IMT effectiveness on lung function when applied in isolation, and they also were performed in people with lung disease (COPD and asthma).[51,52,60] These studies support our results, even though they were carried out on people with lung disease. In our opinion, the absence of any substantive change in spirometric variables may be because the IMT was not focused on the treatment of the expiratory muscles. Only 1 study[61] reported changes in PEF after IMT; however, the investigation was carried out on asthmatic children, so the changes may be because of the development of the respiratory system during the growth period.

Concerning the effect of manual therapy in lung function, a 2012 review[25] established that there is insufficient evidence to support or reject its use in people with COPD due to the lack of studies and low methodological quality. Contradicting our results, studies subsequent to this review reported changes in lung function;[18,62] however, these studies had a small sample size. In addition, these studies were performed in people with chronic neck pain[62] and with pre-established postural disorder (forward head posture).[18,62] Thus, it is possible that treatment focused on the musculoskeletal system could have a greater influence on the respiratory system in this population because of the relationship between both systems.

The combined intervention obtained greater effects in decreasing both postural variables (forward head posture and thoracic kyphosis) than IMT alone. It even exceeded the MDC in the case of the forward head posture;[36] nevertheless, in both cases, this intervention could reflect clinically relevant changes because these differences showed a large effect size.[47,48] These results were predictable because both interventions (manual therapy and motor control exercise) are effective in this postural disorder treatment.[17,18,63] Consequently, in addition to the greatest increase found in MIP in the combined intervention group, these results reinforce the relationship between the musculoskeletal and respiratory system.[4,5,7,58,59]

Limitations

This study has some limitations. First, the short follow-up prevents determining whether the MIP changes are maintained. Second, it was impossible to blind the patient and the therapist because of the type of intervention. Third, clinical effectiveness (the risk ratio, absolute risk reduction, and number needed to treat) was evaluated using an estimation for the minimal clinically important difference

(30% change score of improvement) because the clinical difference is not known; these results could differ if future studies established a minimal clinically important difference for MIP. Fourth, these findings should be interpreted with caution because the study was conducted in healthy people. Thus, the authors recommend evaluating the effectiveness of this combined intervention in people with lung disease. Finally, this study did not use a validated tool to quantify the level of adherence to the domiciliary exercises. Future studies are needed to resolve these limitations. Further studies assessing the effect of this combined intervention with a longer follow-up are needed in people with lung disease such as asthma, cystic fibrosis, or COPD.

Conclusion

Inspiratory muscle training protocol combined with manual therapy and motor control exercise had a greater effect in enhancing MIP than IMT in isolation in moderate smokers in the short term. In addition, both groups showed changes in MIP but not in lung function.

Supplementary Data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jmpt.2017.11.004.

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Contributorship

Concept development (provided idea for the research): I.L.-d.-U.-V.
Design (planned the methods to generate the results): T.D.C., I.L.-d.-U.-V.
Supervision (provided oversight, responsible for organization and implementation, writing of the manuscript): T.D.C., R.L.T., I.L.-d.-U.-V.
Data collection/processing (responsible for experiments, patient management, organization, or reporting data): L.B.-A., P.C.-F.
Analysis/interpretation (responsible for statistical analysis, evaluation, and presentation of the results): R.L.T., I.L.-d.-U.-V.
Literature search (performed the literature search): L.B.-A., P.C.-F., T.D.C., I.L.-d.-U.-V.
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Critical review (revised manuscript for intellectual content, this does not relate to spelling and grammar checking): T.D.C., R.L.T., I.L.-d.-U.-V.

Practical Applications

- Inspiratory muscle training protocol combined with manual therapy and motor control exercise is more effective than IMT in isolation for improving MIP and postural measures in moderate smokers.
- This treatment model has a neuromuscular perspective that integrates into clinical reasoning the influence of the musculoskeletal system and possible dysfunctions on the respiratory system and may be the basis for planning future clinical studies in respiratory disorders.
- The results are interesting because MIP reliability provides essential information to the clinician.
- The MDC data, despite being data from asymptomatic participants, can help determine whether changes after chest physiotherapy are the product of measurement error or the intervention plan itself.
- Treatments raised during the study are simple with no adverse effects. Thus, this therapeutic model is safe to apply in a clinical setting with adult patients.

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