Observational Study

Medicine®

OPEN

Effect of pursed-lip breathing and forward trunk lean positions on regional chest wall volume and ventilatory pattern in older adults

An observational study

Nutsupa Ubolnuar, PT, PhD[a,b], Anong Tantisuwat, PT, PhD[a,*], Witaya Mathiyakom, PT, PhD[c], Premtip Thaveeratitham, PT, PhD[a], Chathipat Kruapanich, PT, PhD[a,d]

Abstract

Pursed-lip breathing (PLB) and forward trunk lean posture (FTLP) are commonly used to relieve dyspnea and improve ventilation in a rehabilitation program. However, their effect on chest wall volumes and movements in older adults without chronic obstructive pulmonary disease has never been investigated. This observational study aimed to identify the effect of combined PLB and FTLP on total and regional chest wall volumes, ventilatory pattern, and thoracoabdominal movement using in older adults. It was hypothesized that the combined PLB with FTLP would result in the highest chest wall volumes among the experimental tasks. Twenty older adults performed 2 breathing patterns of quiet breathing (QB) and PLB during a seated upright (UP) position and FTLP. An optoelectronic plethysmography system was used to capture the chest wall movements during the 4 experimental tasks. Tidal volume (V_T) was separated into pulmonary ribcage, abdominal ribcage, and abdomen volume. The changes in anterior–posterior (AP) and medial–lateral (ML) chest wall diameters at 3 levels were measured and used to identify chest wall mechanics to improve chest wall volumes. The PLB significantly improved ventilation and chest wall volumes than the QB ($P<.05$). V_T of pulmonary ribcage, V_T of abdominal ribcage, and V_T were significantly higher during the PLB + UP ($P<.05$) and during the PLB + FTLP ($P<.01$) as compared to those of QB performed in similar body positions. However, there was no significant in total and regional lung volumes between the PLB + UP and the PLB + FTLP. The AP diameter changes at the angle of Louis and xiphoid levels were greater during the PLB + UP than the QB + UP and the QB + FTLP ($P<.01$). The AP diameter changes at the umbilical level and the ML diameter changes at the xiphoid level were significantly larger during the PLB + FTLP than the QB + FTLP and the QB + UP ($P<.05$). The ML diameter changes at the umbilical level were significantly greater during the PLB + FTLP than the QB + UP ($P<.05$). However, no significant difference in the relative regional chest wall volumes and phase angle among the experimental tasks ($P>.05$). In conclusion, a combined PLB performed in an FTLP or UP sitting could be used as a strategy to improve chest wall volumes and ventilation in older adults.

Abbreviations: AP = anterior–posterior, AoL = angle of Louis, FTLP = forward trunk lean posture, ICC = intraclass correlation coefficient, ML = medial–lateral, OEP = optoelectronic plethysmography, PLB = pursed-lip breathing, QB = quiet breathing, RR = respiratory rate, SEM = standard error of measurement, T_e = expiratory time, T_i = inspiratory time, Umb = umbilicus, UP = upright, V_T = tidal volume, V_{TAB} = tidal volume of abdomen, V_{TRCa} = tidal volume of abdominal ribcage, V_{TRCp} = tidal volume of pulmonary ribcage, Xip = Xiphoid process.

Keywords: chest wall kinematics, forward trunk lean, older adults, optoelectronic plethysmography, pursed-lip breathing

Editor: Saeed Ilbeigi.

This study is supported in part by The Thailand Research Fund (MRG-5980084).

The authors have no conflicts of interest to disclose.

All data generated or analyzed during this study are included in this published article.

[a] Department of Physical Therapy, Faculty of Allied Health Sciences, Chulalongkorn University, Bangkok, Thailand, [b] Department of Physical Therapy, Faculty of Allied Health Sciences, Burapha University, Chonburi, Thailand, [c] Department of Physical Therapy, California State University, Northridge, CA, [d] Faculty of Physical Therapy, Saint Louis College, Bangkok, Thailand.

[*] Correspondence: Anong Tantisuwat, Department of Physical Therapy, Faculty of Allied Health Sciences, Chulalongkorn University, 154 Rama I Road, Pathumwan, Bangkok 10330, Thailand (e-mail: anong.ta@chula.ac.th).

How to cite this article: Ubolnuar N, Tantisuwat A, Mathiyakom W, Thaveeratitham P, Kruapanich C. Effect of pursed-lip breathing and forward trunk lean positions on regional chest wall volume and ventilatory pattern in older adults: an observational study. Medicine 2022;101:4(e28727).

Received: 15 August 2021 / Received in final form: 15 December 2021 / Accepted: 12 January 2022

http://dx.doi.org/10.1097/MD.0000000000028727

1. Introduction

The ability to perform physical activity is essential for older adults to maintain their functional independence and quality of life. Structural and functional changes of the respiratory system associated with aging, including increased stiffness of the costovertebral joints, decreased lung compliance, and weakness of the respiratory muscles,[1] lead to diminished ventilatory capacity. When coupled with increased respiratory demand during physical activities, older adults are likely to experience insufficient ventilation and the sensation of dyspnea during physical activity.[2] It was estimated that approximately 30% of adults 60 years or older reported breathing difficulty when walking on the level or up an incline.[3,4] The sensation of dyspnea has been shown to lead to fatigue, poor exercise endurance, limited physical activity, and poor quality of life in older adults.[2] Therefore, it is important to identify strategies to improve ventilation, chest wall movements and volumes and decrease the sensation of dyspnea in older adults.

Multiple strategies, including modification of body position and pursed-lip breathing, have been proposed as a simple way to relieve dyspnea in older adults[4] and patients with COPD.[5] As commonly observed in patients with COPD, the forward trunk lean posture (FTLP) is commonly achieved by placing the hands or forearms on the thighs while seated. In this position, decreased activation of the upper trapezius was noted in older adults with COPD[5,6] and healthy young adults.[7,8] Additionally, increased activations of the pectoral muscles were noted in older adults with COPD[5,6] and the scalene and sternocleidomastoid muscles in younger adults.[7,8] The changes in these muscle activation patterns led to a greater elevation of rib cage in older adults with COPD[5,6] and a more synchronous movement pattern between the thoracic and abdominal regions,[7,8] which resulted in improved ventilation and decreased the sensation of dyspnea. In patients with COPD, FTLP pushed the abdominal content toward the thoracic cavity placing the flattened diaphragm in a more favorable position to work.[5] Although FTLP has been shown to positively impact ventilation and the sensation of dyspnea in older adults with COPD and healthy young adults, its effect on the total and regional chest wall movements has not been studied in the healthy older adult population.

Pursed-lip breathing (PLB) is another common strategy used to relieve the sensation of dyspnea. An increase in absolute chest wall volume and ventilation associated with PLB has been shown to decrease the sensation of dyspnea in healthy young[9] and older adults[10] and patients with COPD.[5] In healthy older adults, PLB has been shown to improve lung function and respiratory muscle strength, decreasing the load of breathing and the sensation of dyspnea[10] and possibly improving functional capacity.[9] Clinically, PLB is commonly used in combination with FTLP to decrease the sensation of dyspnea in patients with COPD.[11] It is plausible that the combined PLB and FTLP will positively impact the total and regional chest wall volume and ventilatory pattern in older adults.

To our knowledge, the effect of combined PLB and FTLP on the total and regional chest wall volumes and ventilatory patterns in older adults without COPD has never been investigated. Therefore, this study aimed to identify the effect of combined PLB and FTLP on the total and regional chest wall volumes and ventilatory patterns in older adults. It was hypothesized that the combined PLB with FTLP would positively improve regional chest wall volume and ventilation compared to the baseline during quiet breathing (QB). The knowledge gained from this study will provide clinicians with a sound rationale for using these 2 strategies in older adults.

2. Material and methods

2.1. Designs

This cross-sectional study was approved by The Research Ethics Review Committee for Research Involving Human Research Participants, Health Sciences Group, Chulalongkorn University (Protocol number 031.1/61). All participants read and signed the consent form before participating in the study.

2.2. Participants

Twenty older adults aged 60 to 80 years participated in this study. They were included if they had no history and diagnosis of lung disease, had no history of smoking and were currently a nonsmoker, had no other diseases that may limit them from completing the study, and had less than 30 kg/m^2 body mass index. The potential participants were excluded from this study if they were unable to successfully assume the FTLP in a seated position required to complete the study, had a history of chest wall surgery, were having pain and/or discomfort in the chest wall, were taking medication that may affect ventilatory pattern (eg, antidepressants), and consumed alcohol and/or caffeine, or performed vigorous exercise within 2 hours before the data collection session.

The sample size was calculated (G*power program version 3.1 [(Heinrich Heine University Dusseldorf, North Rhine-Westphalia, Germany][12]) based on the results of our pilot study using the same protocol. Since the primary goal was to identify the effect of PLB and FTLP on regional lung volumes, the preliminary results related to regional volumes were used for this calculation. The abdominal tidal volume (V_{TAB}) yielded the largest number of subjects needed for the study and was used for this purpose. With a small effect size of 0.35, a significance level of 0.05, and a statistical power of 0.80, the number of participants needed for this study was 16. With a 20% attrition rate, the total sample size was 20.

2.3. Intervention

The demographic data were collected during the preparatory session. A modified Borg scale and the modified Medical Research Council score were used to assess levels of dyspnea at baseline and physical activity, respectively. The Baecke physical activity questionnaire was used to identify the level of physical activity.

The total and regional chest wall volumes and ventilatory pattern were assessed using an optoelectronic plethysmography (OEP) system. The participants performed 2 breathing patterns of QB and PLB during a self-selected seated upright (UP) position and seated FTLP. During the QB, the participants quietly breathed in and out through the nose as they would typically do.[13] For the PLB, the participants breathed in through the nose and breathed out through partially closed lips. The duration of breathing-out was approximately 2 times longer than that of breathing-in.[14–16] For the UP, the participants comfortably sat as they would when sitting without back support. During the FTLP, the participants leaned forward and placed their forearms

Figure 1. Body positions used in this study: upright position (left) and forward trunk lean position (right).

on their thighs in such a way that the trunk was at about 45° anterior inclination[6,17,18] (Fig. 1).

The combination of 2 breathing strategies and 2 body positions provided 4 experimental tasks: QB + UP, PLB + UP, QB + FTLP, and PLB + FTLP, respectively (Fig. 2). The participants performed 1 minute per trial and 3 trials of each task. The resting period was 1 minute between trials and 2 minutes between tasks. If the participants experienced dyspnea, they were asked to rest until the sensation of dyspnea returned to baseline. Due to the need to adjust the cameras' height and angle and calibrate the data collection volume after the camera adjustment to accommodate the FTLP, the participants started with the UP, followed by the FTLP. The participants performed the QB first within each body position, followed by the PLB to ensure the 1:2 ratio of breathing-in to breathing-out duration. The participants were instructed to perform PLB correctly and asked to demonstrate it to one of the investigators. The correctness of PLB was confirmed by a real-time assessment of the breathing cycle based on the OEP results before the beginning of the data collection.

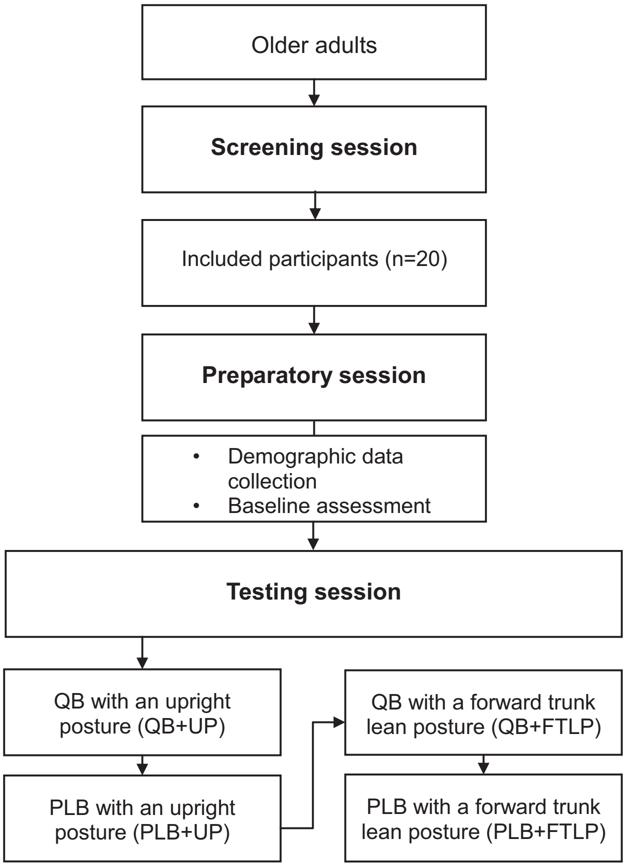

Figure 2. Flow chart of participants.

2.4. Measurement and outcomes

An OEP system (BTS engineering, Milan, Italy) was used to measure the chest wall kinematics during all experimental tasks. Eighty-nine retroreflective markers were attached on the anterior, lateral, and posterior aspects of the participant's chest wall and upper abdominal areas.[19] Eight infrared cameras recorded the positions of these markers at a sampling rate of 60 frames per second. The height and angle of the cameras were set in such a way that at least 2 cameras saw each reflective marker during the data collection. Therefore, the camera setup was adjusted when the participants changed from the UP to the FTLP to ensure that at least 2 cameras saw each marker. The OEP system was calibrated before each data collection session and after adjusting the cameras. All chest wall kinematics variables were tracked and calculated using SMART Tracker (BTS engineering, Milan, Italy) and extracted by a customized software written in MATLAB program (The MathWorks, MA).

The chest wall was divided into 3 regions: pulmonary rib cage, abdominal rib cage, and abdomen[19] (Fig. 3). The volume of each region was calculated by triangulating the marker locations and

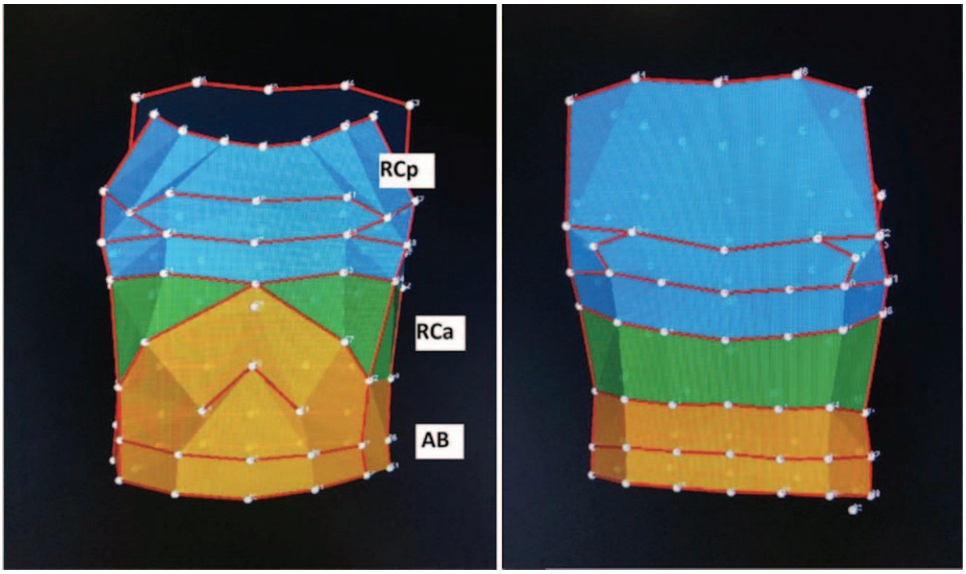

Figure 3. Regional chest wall volume as divided by the optoelectronic plethysmography (OEP): pulmonary rib cage (RCp), abdominal rib cage (RCa), and abdomen (AB).

using Gauss theorem to convert it into volume.[20] The total chest wall tidal volume (V_T) was the sum of 3 regional chest wall volumes, including pulmonary ribcage tidal volume (V_{TRCp}); abdominal ribcage tidal volume (V_{TRCa}), and V_{TAB}. Additionally, each regional chest wall volume contribution relative to the total chest wall V_T was also calculated. The temporal variables, including respiratory rate (RR); inspiratory time (T_i); and expiratory time (T_e), were obtained from the breath-by-breath assessment. These variables were the primary outcomes of this study.

The secondary outcomes of this study were thoracoabdominal movement as indicated by a phase angle and the changes in chest wall diameter in both anterior–posterior (AP) and medial–lateral (ML) directions. The changes in AP chest wall diameter were measured at 3 different levels: the angle of Louis (AoL), xiphoid process (Xip), and umbilicus (Umb) level. The ML diameter changes were also recorded at Xip and Umb level.

2.5. Data analysis

Demographic characteristics and outcome measures were represented in mean ± standard deviation for continuous data and percentage of sample size (%N) for categorical data. Shapiro–Wilk was used to identify the normality of all outcome measures. Intraclass correlation coefficient (ICC [3,3]) was used to determine the between-trial variability, based on a mean-rating (k = 3), absolute agreement, 2-way mixed-effect model. It was then used to identify the standard error of measurement (SEM) of our variables. One-way repeated measures analysis of variance was used to compare the effect of 4 experimental tasks on the outcomes of interest. Posthoc Tukey adjustment was used in multiple comparisons. The significance level was set at 0.05. All data analyses were done using Statistical Package for the Social Sciences software version 22 (International Business Machines, NY).

3. Results

3.1. Baseline characteristics

Ten older adult females and 10 older adult males participated in this study. The baseline characteristics of the participants are presented in Table 1. Most of the participants had at least one co-morbidity. All of them were seen regularly by their physicians, and their conditions were well controlled prior to participating in this study.

Table 1

Baseline characteristics of participants.

Characteristics	Mean ± SD	% (N)
Male/female	10/10	
Age (yr)	64.16 ± 3.7	
Weight (kg)	59.39 ± 9.51	
Height (m)	1.62 ± 0.09	
BMI (kg/m^2)	22.61 ± 2.3	
Co-morbidity		
Respiratory disease		0% (0)
Cardiac disease		5% (1)
Metabolic disease		60% (12)
Neurological disease		0% (0)
Musculoskeletal disorder		5% (1)
Physical activity level	7.9 ± 1.25	
Sedentary		5% (1)
Active		50% (10)
Athlete		45% (9)
Vital sign		
HR (bpm)	66 ± 10	
RR (bpm)	17 ± 3	
SBP (mm Hg)	121 ± 12	
DBP (mm Hg)	76 ± 7	
SpO_2 (%)	97 ± 1	
Lung function		
FVC (L)	5.74 ± 1.51	
FEV_1 (L)	4.68 ± 1.5	
FEV_1/FVC (%)	106.13 ± 12.32	
PEFR (mL)	330 ± 120.8	

BMI = body mass index, DBP = diastolic blood pressure, FVC = force vital capacity, FEV_1 = force expiratory volume in 1 s, HR = heart rate, PEFR = peak expiratory flow rate, RR = respiratory rate, SBP = systolic blood pressure, SD = standard deviation, SpO_2 = oxygen saturation.

Table 2

Intraclass correlation coefficient estimates and standard error of measurement of breathing strategies and body positions on regional chest wall volume, ventilatory pattern, thoracoabdominal movements, and chest wall diameter in older adults.

	QB + UP		PLB + UP		QB + FTLP		PLB + FTLP		
Parameters	ICC	SEM	ICC	SEM	ICC	SEM	ICC	SEM	Level of reliability
Primary outcomes									
RR (bpm)	0.954	1.33	0.963	0.76	0.936	1.71	0.957	0.91	Excellent
T_i (s)	0.956	0.26	0.932	0.26	0.949	0.22	0.963	0.20	Excellent
T_e (s)	0.948	0.37	0.978	0.29	0.958	0.30	0.965	0.38	Excellent
Absolute volumes (L)									
V_T	0.960	0.11	0.947	0.14	0.957	0.09	0.981	0.07	Excellent
V_{TRCp}	0.973	0.02	0.923	0.04	0.933	0.04	0.964	0.03	Excellent
V_{TRCa}	0.965	0.02	0.944	0.03	0.950	0.02	0.936	0.03	Excellent
V_{TAB}	0.951	0.07	0.960	0.09	0.968	0.04	0.986	0.04	Excellent
Relative volumes (%)									
V_{TRCp}	0.967	2.10	0.960	2.29	0.955	2.75	0.944	2.53	Excellent
V_{TRCa}	0.883	1.24	0.902	1.14	0.852	2.08	0.766	2.13	Good to excellent
V_{TAB}	0.958	2.50	0.960	2.49	0.949	3.11	0.958	2.51	Excellent
Secondary outcomes									
Phase angle (°)	0.649	2.46	0.732	2.38	0.304	4.30	0.420	3.40	Poor to moderate
AP change (cm)									
AoL level	0.678	0.10	0.684	0.11	0.716	0.14	0.425	0.17	Poor to moderate
Xip level	0.712	0.09	0.923	0.12	0.857	0.09	0.389	0.28	Poor to excellent
Umb level	0.783	0.07	0.781	0.09	0.220	0.19	0.086	0.62	Poor to moderate
ML change (cm)									
Xip level	0.748	0.21	0.514	0.37	0.620	0.22	0.599	0.58	Moderate
Umb level	0.893	0.07	0.806	0.10	0.740	0.16	0.681	0.38	Moderate to good

° = degrees, AB = abdomen, AoL = angle of Louis, AP change = change of anterior–posterior diameter, bpm = breath per minute, cm = centimeters, EELV = end-expiratory lung volume, EILV = end-inspiratory lung volume, FTLP = forward trunk lean posture, ICC = intraclass correlation coefficient, L = liter, ML change = change of medial–lateral diameter, PLB = pursed-lip breathing, QB = quiet breathing, RR = respiratory rate, s = second, SEM = standard error of measurement, T_e = expiratory time, T_i = inspiratory time, Umb = umbilicus, UP = upright, V_T = tidal volume, V_{TRCa} = tidal volume of abdominal ribcage, V_{TRCp} = tidal volume of pulmonary ribcage, Xip = Xiphoid process.

3.2. Intraclass correlation coefficient (ICC) and standard error of measurement (SEM)

Between-trial reliability and error of measurement of all variables, as indicated by ICC (3,3) and SEM, are presented in Table 2. Good to excellent between-trial reliability (0.766–0.986) and relatively small measurement error were observed in our primary outcome measures of total and regional chest wall volume, and ventilation. In contrast, poor to excellent reliability (0.086–0.893) and relatively large measurement error were noted in our secondary outcome measures.

3.3. Combined effects of body positions and breathing strategies

The effect of combined breathing strategies and body positions on all outcomes is presented in Table 3. T_i and T_e were significantly higher during the PLB + UP than the QB + FTLP ($P<.05$). RR was significantly lower during both PLB tasks (PLB + UP and PLB + FTLP) than both QB tasks (QB + UP and QB + FTLP) ($P<.05$).

A significant effect of combined breathing strategies and body positions was observed on absolute total and regional lung volumes ($P<.001$). V_T, V_{TRCp}, V_{TRCa}, and V_{TAB} were significantly greater during the PLB + UP than the QB + UP ($P<.05$). Likewise, V_T, V_{TRCp}, and V_{TRCa} were greater during the PLB + FTLP than the QB + FTLP ($P<.05$). However, V_T, V_{TRCp}, V_{TRCa}, and V_{TAB} during the QB + UP were significantly greater than the QB + FTLP ($P<.05$). These between-task differences in absolute total and regional lung volumes were accompanied by the chest wall diameter changes.

The AP diameter changes at the AoL and Xip level were significantly larger during the PLB + UP than the QB + UP and the QB + FTLP ($P<.01$). The AP diameter changes at the Umb level and the ML diameter changes at the Xip level were significantly larger during the PLB + FTLP than the QB + FTLP and the QB + UP ($P<.05$). Additionally, the ML diameter changes at the Umb level were significantly greater during the PLB + FTLP than the QB + UP ($P<.05$). These results were in line with the chest wall volumes noted above.

V_{TAB}% showed the highest contribution relative to V_T, followed by V_{TRCp}% and V_{TRCa}%, respectively. However, there was no significant difference in relative regional chest wall volumes among all 4 tasks. Likewise, the phase angle was not significantly different between tasks. These results indicated no significant effect of combined PLB and FTLP on the relative chest wall volume and thoracoabdominal asynchrony.

4. Discussions

This study aimed to identify the effect of combined body positions and breathing strategies on the chest wall volumes and ventilatory patterns in older adults. Significant slower RR and changes in T_i and T_e during the PLB tasks compared to the QB tasks indicated that our participants successfully performed the experimental tasks. Good-to-excellent between-trial reliability and relatively small SEMs indicated the reliability of our primary outcome measures. The PLB + UP and PLB + FTLB significantly increased total and regional absolute chest wall volumes than the QB performed in similar body positions. During the UP, the increases in absolute chest wall volumes were accompanied by significant changes in the AP diameter at the AoL and Xip levels.

Table 3

Combined effects of breathing strategies and body positions on regional chest wall volumes, ventilatory pattern, thoracoabdominal movements, and chest wall diameters in older adults.

Parameters	QB + UP (a)	PLB + UP (b)	QB + FTLP (c)	PLB + FTLP (d)	*P*-value
Primary outcomes					
RR (bpm)	15.69 ± 6.21	10.36 ± 3.96†	16.34 ± 6.76‡	11.37 ± 4.38†,§	<.001*
T_i (s)	1.79 ± 1.25	2.7 ± 1.01	1.83 ± 0.97‡	2.39 ± 1.05	.016*
T_e (s)	2.92 ± 1.64	4.07 ± 1.95	2.7 ± 1.44‡	3.86 ± 2.02	.016*
Absolute volumes (L)					
V_T	0.76 ± 0.56	1.45 ± 0.62†	0.61 ± 0.42‡	1.13 ± 0.53§	<.001*
V_{TRCp}	0.27 ± 0.1	0.48 ± 0.15†	0.21 ± 0.15‡	0.37 ± 0.17§	<.001*
V_{TRCa}	0.13 ± 0.11	0.28 ± 0.13†	0.11 ± 0.08‡	0.21 ± 0.1§	<.001*
V_{TAB}	0.36 ± 0.3	0.69 ± 0.43†	0.3 ± 0.22‡	0.56 ± 0.34	.001*
Relative volumes (%)					
V_{TRCp}	35.52 ± 11.54	33.10 ± 11.44	34.42 ± 12.97	32.74 ± 10.69	.932
V_{TRCa}	17.10 ± 3.62	19.31 ± 3.65	18.03 ± 5.40	18.57 ± 4.41	.413
V_{TAB}	47.36 ± 12.19	47.58 ± 12.44	49.18 ± 13.79	49.55 ± 12.23	.760
Secondary outcomes					
Phase angle (°)	7.94 ± 4.15	5.89 ± 4.59	8.76 ± 5.16	6.29 ± 4.46	.065
AP change (cm)					
AoL level	0.39 ± 0.18	0.63 ± 0.2†	0.37 ± 0.27‡	0.48 ± 0.23	.001*
Xip level	0.38 ± 0.17	0.69 ± 0.45†	0.37 ± 0.24‡	0.55 ± 0.36	.004*
Umb level	0.31 ± 0.15	0.45 ± 0.2	0.39 ± 0.22	0.7 ± 0.65†,§	.001*
ML change (cm)					
Xip level	0.74 ± 0.42	1.18 ± 0.53	0.81 ± 0.35	1.39 ± 0.91†,§	.001*
Umb level	0.41 ± 0.2	0.65 ± 0.22	0.59 ± 0.31	0.98 ± 0.67†	.002*

Data expressed as mean and standard deviation. The primary outcomes were represented as absolute values. The secondary outcomes were represented as changes in the value.

° = degrees, AB = abdomen, AoL = angle of Louis, AP change = change of anterior–posterior diameter, bpm = breath per minute, cm = centimeters, EELV = end-expiratory lung volume, EILV = end-inspiratory lung volume, FTLP = forward trunk lean posture, L = liter, ML change = change of medial–lateral diameter, PLB = pursed-lip breathing, QB = quiet breathing, RCa = abdominal ribcage, RCp = pulmonary ribcage, RR = respiratory rate, s = second, T_e = expiratory time, T_i = inspiratory time, Umb = umbilicus, UP = upright, V_T = tidal volume, V_{TRCa} = tidal volume of abdominal ribcage, V_{TRCp} = tidal volume of pulmonary ribcage, Xip = Xiphoid process.

* Significant of combined effect of breathing strategies and body positions (*P*-value < .05).

† *P*-value < .05 as compared to QB + UP.

‡ *P*-value < .05 as compared to PLB + UP.

§ *P*-value < .05 as compared to QB + FTLP.

In contrast, the changes in chest wall volumes during the FTLP were accompanied by significant increases in the AP and ML diameters at the Umb and Xip levels, respectively. However, the relative contribution of each regional chest wall volume to the total chest wall volume was not altered by the body positions and breathing patterns used in this study.

To our knowledge, this study is the first to identify the effect of breathing patterns and body positions on both total and regional lung volumes in older adults. Overall, the increase in absolute chest wall volumes and associated chest wall diameters during the PLB compared to the QB performed within the same body positions observed in our older adults were in line with those previously reported in patients with COPD.[13,17,21–24] The increase in total and regional chest wall volumes has been shown to provide better gas exchange in the lungs and reduce the sensation of dyspnea.[13,21] An increase in positive end-expiratory pressure observed during the PLB has been shown to decrease the carbon dioxide level and increase the oxygenation in the lungs of both older adults and patients with COPD.[10,25] Our results signify the effect of PLB on improving both total and regional absolute chest wall volumes and possibly its associated positive gas exchange and the relief in the sensation of dyspnea in older adults compared to the QB performed in similar body positions.

The mechanism used to increase chest wall volumes during the PLB differs between the UP and the FTLP. The increase in total and regional chest wall volumes during the PLB + UP compared to the QB + UP was achieved by the significantly greater changes in the upper chest wall AP diameter at the AoL and Xip levels. The AP chest wall diameter changes in the upper chest wall areas indicates the pump handle mechanics generated by the intercostal muscle activation.[8] In contrast, the significant changes in the total and regional chest wall volumes during the PLB + FTLP compared to the QB + FTLP was associated with the AP diameter changes at the Umb level and the ML diameter changes at the Xip. During the FTLP, more relaxed or lengthened abdominal muscles[7] allow the diaphragm[10] to be more effective in pushing the abdominal content downward during the inspiration phase[26] as compared to the UP. As a result, the bucket handle mechanism of the lower rib cage and abdominal areas can be more beneficial to improve chest wall volumes during the FTLP as compared to the UP. Our results indicate the body position-specific mechanisms used to improve total and regional chest wall volumes in the upper and lower chest wall areas noted during the UP and FTLP, respectively.

Although the combined PLB and FTLP was hypothesized to have a positive impact leading to the highest total chest wall volume among the experimental tasks, our results did not support it. In fact, the total and regional lung volumes of the PLB + FTLP were lower, but not significantly, compared to those of the PLB + UP. During the FTLP, our older adults placed their forearms on the thighs to support the upper body. The downward pull of the gravity assists in the AP chest wall diameter changes, particularly in the abdominal region,[27] as indicated by a significantly greater change in AP diameter at the Umb level noted in our study.

However, the need to support the upper body on their arms requires static activation of the chest wall muscles. Kim et al[17] demonstrated that pectoralis major activation during the FTLP, similar to our study, was significantly greater than during the UP.[17] Although the activation of the pectoralis major serves to elevate the rib cage,[17] the nature of static activation of the anterior chest muscles to support the body weight on both arms may stiffen the chest wall. As a result, a nonsignificant smaller change in the AP chest wall diameter at the AoL and Xip levels was observed during the PLB + FTLP compared to the PLB + UP. Likewise, the nonsignificant greater changes in the AP chest wall diameter at the Umb level and the ML diameter changes at the Xip and the Umb levels lead to a nonsignificantly larger change in V_{TRCa} and V_{TAB} during the PLB + FTLP compared to the PLB + UP. As a result, the total chest wall volume during PLB + FTLP did not reach the highest volume compared to the PLB + QB as expected.

Although our results demonstrated significant differences in absolute regional chest wall volumes between the tasks, no significant between-task difference in relative regional chest wall volumes was observed. These results contradicted those of Mendes et al.[28] The differences in research protocol in terms of body positions contribute to the between-study differences in the results. In the study by Mendes et al,[28] the subjects progressively leaned the body backward from a seated UP position to a 45° backward lean and supine position.[28] These backward lean positions limited chest wall expansion in the posterior direction due to the increased resistance of the back support. Additionally, as the body leaned backward, the weight of the heart and abdominal contents progressively added to the resistance against the lung.[27] As a result, the chest wall and intercostal muscles must work relatively harder to move the chest wall against the gravity and the added weight. Thus, the chest wall volume decreased as the subjects increased the backward inclination angle increased.[28] In contrast, our older adults leaned forward and placed their forearms on their thighs. The anterior inclination of the trunk noted during the FTLP allows the gravity to pull the heart and abdominal contents forward, reducing the compressive load on the lungs and allows the lungs to expand freely in both anterior and posterior directions.[29] As a result, the relative contribution of regional chest wall volume remained unchanged between the tasks.

In our study, the highest contribution of V_{TAB} relative to V_T or V_{TAB}% among our experimental tasks is consistent with the results of previous studies in older adults where the volume of the abdominal region was predominant compared to the other regions.[28,30,31] In older adults, decreased chest wall compliance and increased chest wall stiffness limit their chest wall movements and, therefore, the volumes.[32] As a result, the contribution of the rib cage compartment relative to the total volume (V_{TRCp}%) decreased.[28,30] Therefore, to maintain sufficient ventilation and gas exchange, V_{TAB}% must increase in response to the decrease in chest wall compliance and the increase in chest wall stiffness in older adults.[28,30] These results signify the impact of abdominal wall compliance as a factory contributing to sufficient ventilation in older adults.

PLB may improve the coordination of the thorax and abdominal movements, leading to relieving the sensation of dyspnea in older adults. The phase angle has been used to identify thoracoabdominal asynchrony commonly observed during respiratory distress.[33] Our phase angle values of the QB tasks were within the same range (8°–9.9°) previously observed in healthy older adults performing QB.[33] The phase angle during the PLB + UP and the PLB + FTLP trended to be smaller ($P=.065$) than during the QB + UP and the QB + FTLP, respectively. Using a larger sample size in future studies would most likely lead to a significant effect of the PLB on the phase angle outcome. Taken together, these results suggested that PLB may improve the coordination between the ribcage and abdominal regions and possibly lead to the relief of dyspnea in older adults compared to QB.

4.1. Limitations

There were a few limitations in this study. Firstly, our results may suffer from a testing order effect. In this study, the order of experimental tasks was not randomized due to the need to establish the baseline during the QB + UP and recalibrate the OEP system to capture all makers during the FTLP tasks. As a result, our subjects may experience physical and mental fatigue, leading to the deterioration of the subject's ability to perform the experimental tasks. However, subjects were allowed to rest sufficiently between trials and tasks to minimize the fatigue. Additionally, the high ICC values of the primary outcomes observed across all experimental tasks led us to believe that the testing order did not significantly affect our results. Secondly, we did not specifically investigate the effect of gender on our outcomes. However, we believe that the equal number of female and male subjects minimized the gender effect. Lastly, our study only identified the acute effect of the combined body position and breathing patterns on the chest wall volumes and ventilatory patterns. Randomized controlled trials with a prospective cohort study with a more extended training session and follow-up periods will be needed to confirm the benefits of the experimental tasks in older adults.

4.2. Clinical implication

Our results provide a sound rationale for using both PLB + UP and PLB + FTLP as a strategy to improve ventilatory pattern, absolute total and regional chest wall volumes, and chest wall diameters in older adults. PLB + UP significantly facilitates the pump handle mechanics of the upper chest wall region. In contrast, the PLB + FTLP enables the bucket handle mechanics of the lower chest wall region. Understanding the changes in total and regional chest wall volumes and movements provides insights into the mechanisms to improve ventilation, which serves as a sound rationale for exploring strategies for relieving dyspnea in older adults. Since our study evaluated the effect of combined body position and breathing pattern for only 1 minute each intervention, the abovementioned benefits were limited to a short period. Thus, the long-term effect of PLB + UP and PLB + FTLP on regional chest wall volumes and thoracoabdominal movement in older adults need further evaluation.

5. Conclusion

PLB performed in either an UP sitting position or a forward trunk lean acutely improves lung ventilation, absolute total, and regional chest wall volumes in older adults compared to QB performed in the same positions. Randomized controlled trials with larger sample sizes and more extended training and follow-up sessions will be needed to demonstrate the long effects of these combined strategies.

Acknowledgments

The research fund was used to provide compensation to study participants and research assistants and cover the expense related to materials used in the study.

Author contributions

Conceptualization: Nutsupa Ubolnuar, Anong Tantisuwat, Witaya Mathiyakom, Premtip Thaveeratitham.
Data curation: Nutsupa Ubolnuar, Anong Tantisuwat, Chathipat Kruapanich.
Formal analysis: Nutsupa Ubolnuar, Witaya Mathiyakom.
Funding acquisition: Anong Tantisuwat.
Investigation: Nutsupa Ubolnuar, Anong Tantisuwat, Witaya Mathiyakom, Premtip Thaveeratitham.
Methodology: Nutsupa Ubolnuar, Anong Tantisuwat, Witaya Mathiyakom, Premtip Thaveeratitham.
Project administration: Anong Tantisuwat.
Supervision: Anong Tantisuwat, Witaya Mathiyakom, Premtip Thaveeratitham.
Writing – original draft: Nutsupa Ubolnuar.
Writing – review & editing: Anong Tantisuwat, Witaya Mathiyakom.

References

[1] Sharma G, Goodwin J. Effect of aging on respiratory system physiology and immunology. Clin Interv Aging 2006;1:253–60.
[2] Miner BA-O, Tinetti ME, Van Ness PH, et al. Dyspnea in community-dwelling older persons: a multifactorial geriatric health condition. J Am Geriatr Soc 2016;64:2042–50.
[3] Mahler DA, Baird JC. Mahler DA, O'Donnell DE. Dyspnea in the elderly. Dyspnea: Mechanisms, Measurement, and Management 2nd edBoca Raton (FL): Taylor & Francis; 2005;19–28.
[4] Mahler DA. Evaluation of dyspnea in the elderly. Clin Geriatr Med 2017;33:503–21.
[5] Gosselink R. Controlled breathing and dyspnea in patients with chronic obstructive pulmonary disease (COPD). J Rehabil Res Dev 2003;40(5 Suppl 2):25–33.
[6] Kim K-s, Lee W-H, Cynn H-S, Kwon O-Y, Yi C-H. Influence of sitting posture on tidal volume, respiratory rate, and upper trapezius activity during quiet breathing in patient with chronic obstructive pulmonary disease. Sci Res Essays 2013;8:1166–70.
[7] Mesquita Montes A, Gouveia S, Crasto C, et al. Abdominal muscle activity during breathing in different postural sets in healthy subjects. J Bodyw Mov Ther 2017;21:354–61.
[8] Mesquita Montes A, Tam C, Crasto C, 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;61:167–76.
[9] Damle SJ, Shetye JV, Mehta A. Immediate effect of pursed-lip breathing while walking during six minute walk test on six minute walk distance in young individuals. Indian J Physiother Occup Ther 2016;10:56–61.
[10] Jansang S, Mickleborough T, Suksom D. Effects of pursed-lip breathing exercise using windmill toy on lung function and respiratory muscle strength in the elderly. J Med Assoc Thai 2016;99:1046–51.
[11] O'Neill S, McCarthy DS. Postural relief of dyspnoea in severe chronic airflow limitation: relationship to respiratory muscle strength. Thorax 1983;38:595–600.
[12] Faul F, Erdfelder E, Lang AG, Buchner A. G*Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. Behav Res Methods 2007;39:175–91.
[13] Bianchi R, Gigliotti F, Romagnoli I, et al. Patterns of chest wall kinematics during volitional pursed-lip breathing in COPD at rest. Respir Med 2007;101:1412–8.
[14] Jones AY, Dean E, Chow CC. Comparison of the oxygen cost of breathing exercises and spontaneous breathing in patients with stable chronic obstructive pulmonary disease. Phys Ther 2003;83:424–31.
[15] Visser FJ, Ramlal S, Dekhuijzen PN, Heijdra YF. Pursed-lips breathing improves inspiratory capacity in chronic obstructive pulmonary disease. Respir Int Rev Thorac Dis 2011;81:372–8.
[16] Ramos E, Vanderlei L, Ramos D, Teixeira L, Pitta F, Veloso M. Influence of pursed-lip breathing on heart rate variability and cardiorespiratory parameters in subjects with chronic obstructive pulmonary disease (COPD). Braz J Phys Ther 2009;13:288–93.
[17] Kim K-s, Byun M-k, Lee W-h, Cynn H-s, Kwon O-y, Yi F C-h. Effects of breathing maneuver and sitting posture on muscle activity in inspiratory accessory muscles in patients with chronic obstructive pulmonary disease. Multidiscip Respir Med 2012;7:9–19.
[18] Kristjansdottir A, Asgeirsdottir M, Beck H, Hannesson P, Ragnarsdottir M. Respiratory movements of patients with severe chronic obstructive lung disease and emphysema in supine and forward standing leaning. Open J Respir Dis 2015;5:1–9.
[19] Parreira VF, Vieira DSR, Myrrha MAC, Pessoa IMBS, Lage SM, Britto RR. Optoelectronic plethysmography: a review of literature. Braz J Phys Ther 2012;16:439–53.
[20] Massaroni C, Carraro E, Vianello A, et al. Optoelectronic plethysmography in clinical practice and research: a review. Respir Int Rev Thorac Dis 2017;93:339–54.
[21] Bianchi R, Gigliotti F, Romagnoli I, et al. Chest wall kinematics and breathlessness during pursed-lip breathing in patients with COPD. Chest 2004;125:459–65.
[22] Tiep BL, Burns M, Kao D, Madison R, Herrera J. Pursed lips breathing training using ear oximetry. Chest 1986;90:218–21.
[23] Breslin EH. The pattern of respiratory muscle recruitment during pursed-lip breathing. Chest 1992;101:75–8.
[24] Ubolnuar N, Tantisuwat A, Thaveeratitham P, et al. Effects of pursed-lip breathing and forward trunk lean postures on total and compartmental lung volumes and ventilation in patients with mild to moderate chronic obstructive pulmonary disease: an observational study. Medicine 2020;99:51.
[25] Nguyen J, Duong H. Pursed-lip Breathing. 2019. StatPearls [Internet]. Available at: https://www.ncbi.nlm.nih.gov/books/NBK545289/. Accessed January 2019.
[26] Shephard RJ. Aging, respiratory function, and exercise. J Aging Phys Act 1993;1:59–83.
[27] Barnas George M, Green Michael D, Mackenzie Colin F, et al. Effect of posture on lung and regional chest wall mechanics. Anesthesiology 1993;78:251–9.
[28] Mendes LPDS, Vieira DSR, Gabriel LS, et al. Influence of posture, sex, and age on breathing pattern and chest wall motion in healthy subjects. Braz J Phys Ther 2020;24:240–8.
[29] Mezidi M, Guérin C. Effects of patient positioning on respiratory mechanics in mechanically ventilated ICU patients. Ann Transl Med 2018;6:384.
[30] Muniz de Souza H, Rocha T, Campos SL, et al. Acute effects of different inspiratory efforts on ventilatory pattern and chest wall compartmental distribution in elderly women. Respir Physiol Neurobiol 2016;227:27–33.
[31] Britto RR, Zampa CC, de Oliveira TA, Prado LF, Parreira VF. Effects of the aging process on respiratory function. Gerontology 2009;55:505–10.
[32] Pruthi N, Multani N. Influence of age on lung function tests. J Exerc Sci Physiother 2012;8:1–6.
[33] Alves GS, Britto RR, Campos FC, Vilaça ABO, Moraes KS, Parreira VF. Breathing pattern and thoracoabdominal motion during exercise in chronic obstructive pulmonary disease. Braz J Med Biol Res 2008; 41:945–50.