Effects of Pursed-Lip Breathing Exercise Using Windmill Toy on Lung Function and Respiratory Muscle Strength in the Elderly

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Background: *Aging results in decline in lung function and reduction of respiration muscle strength.*
Objective: *To investigate whether pursed-lip breathing exercise, using windmill toy, can improve lung function, and respiratory muscle strength in the elderly.*
Material and Method: *Fifty-four older men and women (aged 60 to 75 years) were randomly assigned to three groups, control (CON, n = 18), diaphragmatic breathing exercise (DBE, n = 18), and pursed-lips breathing exercise (PBE, n = 18) group. The DBE group was subjected to deep breathing exercises by slowly inhaling and exhaling through the nose. The PBE group was subjected to a breathing maneuver that comprised of inhaling gently through the nose, and then slowly and gently squeeze air out through pursed-lips using windmill toy to control the airflow. Both breathing exercise groups (PBE and DBE) performed the maneuvers three times per week for 12 weeks. Shortness of breath, 6-minute walk distance (6MWD), lung function, and respiratory muscle strength were measured at pre- and post-test.*
Results: *Shortness of breath scores, the ratio of force vital capacity (FVC), forced expiratory volume in one second (FEV_1), and maximal inspiratory pressure (MIP) were significantly increased (all $p<0.05$) in the PBE group compared to CON and DBE groups at weeks 12. However, no significant differences in maximum expiratory pressure (MEP) were observed in all three groups.*
Conclusion: *Pursed-lips breathing exercise using a windmill toy is an effective breathing exercise intervention for improving lung function and respiratory muscle strength in the elderly.*

Keywords: *Pursed-lip breathing exercise, Diaphragmatic breathing exercise, Respiratory muscle strength, Windmill toy*

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A consequence of aging is a degeneration in many physiological variables, with the most important being, sarcopenia and the subsequent loss of muscle strength[1]. Aging is associated with a decrease in lung function and respiratory muscle function[2], with respiratory muscle strength declining at a rate of 8 to 15% per decade of life after 50 years of age[3]. The deficit in respiratory muscle strength affects physical performance leading to diminish in exercise tolerance, deterioration of gait, and decrease of the quality of life (QOL) with advancing age[4]. The reduction of respiratory muscle function in the elderly thus makes this population more vulnerable to disease and disability[5]. Breathing exercise have long been recognized as an effective intervention to reduce breathlessness, and thus improve pulmonary function and QOL by strengthening the respiratory muscles[6]. Previous studies using deep breathing exercises had found that it increased lung function and respiratory muscle strength and endurance in the aging population[7,8]. Pursed-lips breathing is an intervention routinely taught as a breathing exercise in pulmonary rehabilitation programs. The exhalation technique is performed through resistance created by pursing the lips[9]. Previous studies had shown that pursed-lips breathing provided a sustained improvement in exertional dyspnea and physical function in COPD patients[10]. Therefore, the pursed-lips breathing technique should be considered for the aging population[11,12]. In the present study, we used a portable hand-held windmill toy, positioned in front of the subject mouth, as the subject exhaled through tightly pressed pursed-lips. The purpose of the present study was to determine the effect of pursed-lip breathing exercise, using windmill toy, on lung function,

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respiratory muscle strength, and exercise tolerance in the elderly.

Material and Method

Subjects

Fifty-four elderly subjects [male (n = 16) and female (n = 38)], aged 60 to 75 years, were recruited from the Wipawadee Elderly Community in Bangkok, Thailand. The inclusion criteria were normal mobility and independent self-care, exclusion criteria were subjects with history of chronic lung disease and participated in any exercise program in the past six months. All the subjects were instructed not to alter their physical activity, dietary, and lifestyle throughout the intervention period.

The eligible participants were stratified based on vital capacity and then randomly allocated to three groups using the random number table generated by the computer, control (CON, n = 18), diaphragmatic breathing exercise (DBE, n = 18), and pursed-lips breathing exercise (PBE, n = 18). Participants were excluded if they completed less than 80% of breath training sessions. Fourteen participants did not complete the study. The reasons for exclusion included loss of follow-up and physical discomfort. Those remaining subjects comprised of 13 participants in the CON group, 13 participants in the DBE group, and 14 participants in the PBE group.

The present study was approved by the Ethics Review Committee for Research Involving Human Research Subjects, Health Science Group, Chulalongkorn University and conducted according to the Helsinki Declaration. Written informed consent was obtained from all participants.

Study design

The present study was conducted as a randomized parallel group design. On the first day, the participants reported to the laboratory in the morning. Their general physiological characteristics, cardiovascular fitness, modified shortness of breath questionnaire (SOBQ), lung function, and respiratory muscle strength were determined. All the post measurements were performed after 12 weeks of the study.

Breathing exercise protocol

Diaphragmatic breathing exercise (DBE)

The DBE is re-establishing a proper breathing pattern, increase diaphragm activity. The participants were asked to sit in a comfortable position and performed deep breathing exercise consist of prolong and slow inhaled and exhaled through the nose[6]. The participants performed the breathing exercise by inhale and exhale at ratio of 1:2 for 10 times, done for three sets, with 3 minutes rest between the sets. The participants placed one hand on their upper chest and another just below the rib cage. They would feel the diaphragm moved as they breath in and stomach moved out against the hands.

Pursed-lips breathing exercise (PBE)

The PBE technique is a variable expiratory resistance that is created by constriction of the lips. The participants were asked to sit in a comfortable position and took an easy breath in through the nose, then, slowly and gently squeezed air out through pursed-lips[10]. The participants performed the inhalation and exhalation time at the ratio of 1:3 for 10 times, done for three sets with 3 minutes rest between sets. In the present study, the participants controlled the pursed-lip breathing airflow by using a windmill toy for the effective breathing. The six-leafs windmill toy was placed far from the mouth for 25 cm in week 1 to 6, and for 30 cm in week 7 to 12. In order to avoid the distance error, each windmill toy had a holder to fix it.

Measurements

Heart rate and blood pressure

Heart rate (HR) and blood pressure were taken after a 10-minute rest period using digital a sphygmomanometer (GE Diamap CARESCAPEV100, USA). Body weight was measured using a bioelectrical impedance analyzer (Omron, Japan). Body mass index (BMI) was calculated as body weight/height^2.

Cardiovascular fitness

Cardiovascular fitness was assessed with 6-minute walk distance (6MWD) test and expressed as the meters that the participants walked in six minutes around a 50-meter course. Maximal oxygen consumption (VO_2max) was calculated as equation; male VO_2max = 70.161 + (0.023 x 6MWD) - (0.276 x weight) - (0.193 x RHR) - (0.191 x age) and female VO_2max = 70.161 + (0.023 x 6MWD) - (0.276 x weight) - (6.79) - (0.193 x RHR) - (0.191 x age)[13].

Dyspnea

Dyspnea was assessed using modified shortness of breath questionnaires in Thai language (modified from the University of California, San Diego, shortness of breath questionnaires; SOBQ). The modified shortness of breath questionnaires is a 6-items tool for measuring self-reported shortness of breath severity during the past week while performing daily living activities on 6-point scale. Score range from 0 to 30, with the lower number associated with less shortness of breath.

Lung function

Lung function was assessed using a calibrated computerized pneumotachograph spirometer (Spirobank G, MIR, USA). The tests were simple spirometry with provided data for the following variables: vital capacity (VC), forced vital capacity (FVC), forced expiratory volume in one second (FEV_1). The protocol in the study followed the standards required by the American Thoracic Society (ATS) recommendations[14].

Respiratory muscle strength

The measurement of the maximal inspiratory pressure (MIP) and maximal expiratory pressure (MEP) were performed through a digital manometer (MicroRPM, Care Fusion, UK). The measurements were collected according to the American Thoracic Society guidelines[15]. The measured with a sensitivity range between 0 and 300 cmH_2O of pressure. The measurements were repeated until three readings were obtained with a variance of less than 10%[16,17].

Table 1. General characteristics of the control (CON), diaphragmatic breathing exercise (DBE), and pursed-lips breathing exercise (PBE) groups

	CON (n = 13)	DBE (n = 13)	PBE (n = 14)
Age (years)	66.23±1.49	68.31±1.60	65.00±0.99
Weight (kg)	66.58±2.78	61.92±2.58	60.36±3.33
Height (cm)	160.54±3.08	161.00±2.49	160.57±2.38
BMI (kg/m^2)	25.82±0.84	23.50±0.79	23.27±0.80
HR (bpm)	111.38±2.26	115.46±2.44	113.00±2.40
SBP (mmHg)	130.00±1.78	126.92±2.06	127.07±1.75
DBP (mmHg)	83.38±1.45	85.31±1.58	86.14±1.52

BMI = body mass index; HR = heart rate; SBP = systolic blood pressure; DBP = diastolic blood pressure
Values are expressed as mean ± SEM

Statistical analysis

Data were expressed as mean ± SEM. SPSS version 17 for Windows statistical software was used to analyze the data. A 3x2 (group x time) repeated measured ANOVA, followed by Tukey's multiple comparison was used to determine the general characteristics, cardiovascular fitness, shortness of breath score, lung function, and respiratory muscle strength variables. Differences were considered significant at $p<0.05$.

Results

The general physiological characteristics data of participants were summarized in Table 1. There were no significant differences in weight, height, and body mass index among CON, DBE, and PBE groups at baseline.

Cardiovascular fitness presented by 6MWD and VO_2max as well as shortness of breath data were shown in Table 2. The results demonstrated that there were no significant differences in 6MWD and VO_2max among three groups. However, shortness of breath score was decreased significantly in PBE group after 12 weeks of training ($p<0.05$).

As illustrated in Table 3, after 12 weeks, the PBE had higher ($p<0.05$) FEV_1/FVC than the CON and DBE groups. FEV_1 were higher ($p<0.05$) in the PBE than in the CON at post-test. However, FVC was not different among three groups.

As shown in Table 4, MIP were increased ($p<0.05$) only in the PBE group. The PBE group had

Table 2. Cardiovascular fitness and shortness of breathing score of the CON, DBE, and PBE groups over the baseline (0 week) and post-test (12 weeks)

	CON (n = 13)		DBE (n = 13)		PBE (n = 14)	
	Pre-test	Post-test	Pre-test	Post-test	Pre-test	Post-test
6MWD (meters)	349.00±14.10	378.15±23.15	338.15±20.17	379.00±19.44	358.50±14.32	368.86±13.74
VO_2max (ml/kg/minute)	32.97±1.97	32.38±1.97	34.34±1.97	35.18±1.97	35.47±1.90	37.25±1.90
SOBQ (scores)	7.46±0.88	7.08±0.83	7.31±0.73	6.70±0.94	8.35±0.75	7.64±0.90*

6MWD = 6-minute walk distance; VO_2max = maximal oxygen consumption; SOBQ = shortness of breath questionnaires
Values are expressed as mean ± SEM
* Significant differences compared with pre-test in the same group ($p<0.05$)

Table 3. Lung function of the CON, DBE, and PBE groups over the baseline (0 week) and post-test (12 weeks)

	CON (n = 13)		DBE (n = 13)		PBE (n = 14)	
	Pre-test	Post-test	Pre-test	Post-test	Pre-test	Post-test
FVC (L)	1.59±0.24	1.57±0.24	1.62±0.24	1.75±0.24	2.12±0.24	2.00±0.24
FEV_1 (L)	1.42±0.24	1.39±0.24	1.29±0.24	1.59±0.24	1.91±0.24	1.91±0.24†
FEV_1/FVC (%)	77.17±5.71	76.87±5.71	70.45±5.71	79.40±5.71	78.74±5.71	86.70±5.71*†

FVC = forced vital capacity; FEV_1 = forced expiratory volume in 1 second
Values are expressed as mean ± SEM
* Significant differences compared with pre-test in the same group (p<0.05)
† Significant differences compared with con-group at the same time (p<0.05)

Table 4. Respiratory muscle strength of the CON, DBE, and PBE groups over the baseline (0 week) and post-test (12 weeks)

	CON (n = 13)		DBE (n = 13)		PBE (n = 14)	
	Pre-test	Post-test	Pre-test	Post-test	Pre-test	Post-test
MIP (cmH_2O)	52.54±9.40	52.77±9.40	57.15±9.40	59.90±9.40	51.50±9.23	72.30±9.23*†
MEP (cmH_2O)	58.38±13.93	56.69±13.93	64.15±13.93	69.90±13.93	60.85±13.68	75.43±13.68

MIP = maximal inspiratory pressure; MEP = maximal expiratory pressure
Values are expressed as mean ± SEM
* Significant differences compared with pre-test in the same group (p<0.05)
† Significant differences compared with con-group at the same time (p<0.05)

significantly greater MIP than the CON group. MEP tended to be higher in the DBE and PBE groups but not significant.

Discussion

The major finding of the present study was that pursed-lip breathing exercise provided improvement of dyspnea in the elderly. Lung function and maximal inspiratory pressure were higher following 12 weeks of pursed-lip breathing exercise when compared with the control group and the diaphragmatic breathing group. Although no significant differences between groups were observed for FVC and FEV_1, an increase in FVC/FEV_1 occurred after the 12 weeks pursed-lip breathing. To our knowledge, this is the first study to evaluate the effects of a handheld device that controls airflow during pursed-lip breathing on lung function and respiratory muscle strength in the elderly.

Aging is associated with increased breathlessness and dyspnea(18). Symptoms of breathlessness may contribute to increasing inactivity with aging, resulting in respiratory muscle atrophy(19). The present study had demonstrated that dyspnea, assessed by a shortness of breath questionnaire, decreased after pursed-lip breathing exercise in the elderly. Robert et al (2009) performed a review of pursed-lip breathing and concluded that 40% of dyspnea was relieved when pursed-lip breathing was used(20). It has been suggested that the slow breathing frequency used with pursed-lip breathing exercise, and the sustained increase in inspiratory muscle strength produced over time leads to less respiratory muscle force generated with each breath, therefore, may reduce motor output to the respiratory muscles, and decrease the perceived sense of respiratory effort(10). Thus, the improvement of inspiratory muscle strength following pursed-lip breathing exercise, as shown in our study, may explain the observed improvement in breathlessness.

The decrease in maximal respiratory pressure, as a function of age, is between 0.8 and 2.7 cmH_2O per year. MIP is an index of the strength of diaphragm, whereas MEP measures the strength of the abdominal and intercostal muscles(21). The present study confirmed data from the previous study(21) that the increase in MIP was greater after pursed-lip breathing exercise. A likely mechanism to explain our finding is that contraction of the abdominal muscles with pursed-lip breathing facilitate expiration, by increasing intra-abdominal pressure and by cephalad displacement of the diaphragm and the rib cage in the thorax. This, in turn, may reduce functional residual capacity below the passively determined end-expiratory volume, thereby making available elastic energy in the chest wall to use by the inspiratory muscles, and lengthening the inspiratory muscle fibers and thus providing more tension generate for any given level of activation(12). Moreover, in the present study, the use of the windmill toy may lead to the maintenance of a positive pressure in the airways and thus lead to longer and stronger exhalation, which in turn, lead to improved efficiency of ventilation and strengthening of the diaphragm.

In the present study, no improvement in cardiovascular fitness, as assessed by a 6-minute walk distance test, was observed between the diaphragmatic and pursed-lip breathing groups. This possibly indicated that these breathing exercises may have been insufficient to induce adaptive response in the cardiovascular system.

Conclusion

The present study showed that 12 weeks of pursed-lip breathing exercise, using a windmill toy, is an effective therapeutic intervention that can be used to lessen dyspnea in the elderly. Therefore, pursed-lip breathing exercise, using a windmill toy, should be promoted as a beneficial breathing exercise, which is safe, and can be used by the elderly who experience breathlessness.

What is already known on this topic?

Aging is associated with increased dyspnea/ breathlessness and decline in lung function and respiratory muscle strength. The breathing control exercises, diaphragmatic breathing, respiratory muscle training, and pursed-lip breathing, are being used to improve dyspnea. However, the breathing method techniques should be improved to be a more effective intervention for the elderly populations.

What this study adds?

In the present study, we used a portable hand held windmill toy to induce longer and stronger exhalation in pursed-lip breathing. Our results demonstrated that the method made greater improvement in dyspnea, lung function, and maximal inspiratory pressure than diaphragmatic breathing exercise. The present study indicated that pursed-lip breathing exercise using a windmill toy, a novel breathing exercise technique, is an effective therapeutic intervention that can be used to decrease dyspnea in the elderly.

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Potential conflicts of interest

None.

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ผลของการฝึกการหายใจแบบห่อปากโดยใช้กังหันลมของเล่นที่มีต่อการทำงานของปอดและความแข็งแรงของกล้ามเนื้อหายใจในผู้สูงอายุ

สราวุธ จันทร์แสง, Timothy Mickleborough, ดรุณวรรณ สุขสม

ภูมิหลัง: *ผู้สูงอายุมีการเสื่อมลงของสมรรถภาพของปอดและมีความแข็งแรงของกล้ามเนื้อหายใจลดลง*
วัตถุประสงค์: *เพื่อศึกษาว่าการหายใจแบบห่อปากโดยใช้กังหันลมของเล่นสามารถเพิ่มสมรรถภาพของปอดและความแข็งแรงของกล้ามเนื้อหายใจในผู้สูงอายุได้หรือไม่*
วัสดุและวิธีการ: *ผู้สูงอายุ จำนวน 54 คน ทั้งเพศชายและหญิง อายุ 60-75 ปี ทำการแบ่งกลุ่มออกเป็น 3 กลุ่ม ได้แก่ กลุ่มควบคุม จำนวน 18 คน กลุ่มการหายใจโดยใช้กะบังลม จำนวน 18 คน และกลุ่มการหายใจแบบห่อปากโดยใช้กังหันลมของเล่น จำนวน 18 คน โดยกลุ่มที่ทำการฝึกการหายใจแบบใช้กะบังลมจะทำการหายใจเข้าและออกทางจมูก ช้า ๆ และกลุ่มการฝึกการหายใจแบบห่อปากโดยใช้กังหันลมของเล่น จะทำการหายใจเข้าทางจมูกและหายใจออกโดยการห่อปากเป่าลมไปที่กังหันลมของเล่น เพื่อควบคุมการไหลของอากาศในการหายใจออก ทำการฝึก 3 ครั้งต่อสัปดาห์ เป็นเวลา 12 สัปดาห์ ทำการวัดตัวแปรต่าง ๆ ได้แก่ ภาวะการหายใจสั้นตื้น ระยะทางที่เดินได้ภายในเวลา 6 นาที สมรรถภาพของปอด และความแข็งแรงของกล้ามเนื้อหายใจก่อนและหลังการทดลอง*
ผลการศึกษา: *ภายหลัง 12 สัปดาห์ กลุ่มการหายใจแบบห่อปากโดยใช้กังหันลมของเล่นมีภาวการณ์หายใจสั้นตื้นในการมีกิจกรรมต่าง ๆ ในชีวิตประจำวันลดลง มีค่าสัดส่วนของความจุปอดและการหายใจออกใน 1 วินาที สูงขึ้น และมีความแข็งแรงของกล้ามเนื้อหายใจเข้าสูงขึ้นอย่างมีนัยสำคัญทางสถิติที่ระดับ 0.05 เมื่อเทียบกับกลุ่มควบคุมและกลุ่มการหายใจแบบใช้กะบังลม อย่างไรก็ตามไม่พบการเปลี่ยนแปลงของความแข็งแรงของกล้ามเนื้อหายใจออกในทั้ง 3 กลุ่มการทดลอง*
สรุป: *การหายใจแบบห่อปากโดยใช้กังหันลมของเล่น เป็นรูปแบบการหายใจที่มีประสิทธิภาพสำหรับผู้สูงอายุ โดยช่วยทำให้สมรรถภาพของปอดและความแข็งแรงของกล้ามเนื้อหายใจในผู้สูงอายุเพิ่มขึ้น*