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

Sarawut Jansang BSc*, Timothy Mickleborough PhD**, Daroonwan Suksom PhD*

* Faculty of Sports Science, Chulalongkorn University, Bangkok, Thailand
** Department of Kinesiology, School of Public Health, Indiana University, Bloomington, USA

Background: Aging results in decline in lung function and reduction of respiratory 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 (FEV1), 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
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[9]. 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-leaves 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/height2.

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 ($\text{VO}_{2}\text{max}$) was calculated as equation; male $\text{VO}_{2}\text{max} = 70.161 + (0.023 \times 6\text{MWD}) - (0.276 \times \text{weight}) - (0.193 \times \text{RHR}) - (0.191 \times \text{age})$ and female $\text{VO}_{2}\text{max} = 70.161 + (0.023 \times 6\text{MWD}) - (0.276 \times \text{weight}) - (6.79) - (0.193 \times \text{RHR}) - (0.191 \times \text{age})^{11}$.

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 (FEV1). 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 cmH2O of pressure. The measurements were repeated until three readings were obtained with a variance of less than 10%(16,17).

**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 VO2max as well as shortness of breath data were shown in Table 2. The results demonstrated that there were no significant differences in 6MWD and VO2max 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) FEV1/FVC than the CON and DBE groups. FEV1 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

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<th>Table 1. General characteristics of the control (CON), diaphragmatic breathing exercise (DBE), and pursed-lips breathing exercise (PBE) groups</th>
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BMI = body mass index; HR = heart rate; SBP = systolic blood pressure; DBP = diastolic blood pressure
Values are expressed as mean ± SEM

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<th>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)</th>
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<td>6MWD (meters)</td>
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<td>VO2max (ml/kg/minute)</td>
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<td>SOBQ (scores)</td>
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6MWD = 6-minute walk distance; VO2max = 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)
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 FEV₁, an increase in FVC/FEV₁, 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. Symptoms of breathlessness may contribute to increasing inactivity with aging, resulting in respiratory muscle atrophy. 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. 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.

The decrease in maximal respiratory pressure, as a function of age, is between 0.8 and 2.7 cmH₂O per year. MIP is an index of the strength of diaphragm, whereas MEP measures the strength of the abdominal and intercostal muscles. The present study confirmed data from the previous study 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.

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 handheld 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.

Acknowledgments
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Potential conflicts of interest
None.

References


ผลของการฝึกการหายใจแบบหูฟริ้นโดยใช้กังหันลมของเล่นที่มีผลต่อการทำงานของปอดและความแข็งแรงของกล้ามเนื้อหายใจในผู้สูงอายุ

สาสตร์ อัณฑชัย, Timothy Mickleborough, ศรุณวรรณ สุขสม

ภูมิหลัง: ผู้สูงอายุมีการเปลี่ยนแปลงของสมรรถภาพของปอดและมีความแข็งแรงของกล้ามเนื้อหายใจลดลง

วัตถุประสงค์: เพื่อศึกษาการหายใจแบบหูฟริ้นโดยใช้กังหันลมของเล่นสามารถเพิ่มสมรรถภาพของปอดและความแข็งแรงของกล้ามเนื้อหายใจในผู้สูงอายุได้หรือไม่

วัสดุและวิธีการ: ผู้สูงอายุ จำนวน 54 คน ทั้งเพศชายและหญิง อายุ 60-75 ปี ทำการแบ่งกลุ่มออกเป็น 3 กลุ่ม ได้แก่ กลุ่มควบคุม จำนวน 18 คน กลุ่มการหายใจโดยใช้กะบังลม จำนวน 18 คน และกลุ่มการหายใจแบบหูฟริ้นโดยใช้กังหันลมของเล่น จำนวน 18 คน โดยผู้ที่ทำการฝึกการหายใจให้ระบบจะทำการหายใจเข้าและออกทางจมูก ช้า ๆ และกลุ่มการฝึกการหายใจแบบหูฟริ้นโดยใช้กังหันลมของเล่น จะทำการหายใจเข้าทางจมูกและหายใจออกโดยการหูฟริ้นไปที่กังหันลมของเล่น เพื่อควบคุมการไหลของอากาศในการหายใจ ทำการฝึก 3 ครั้งต่อสัปดาห์ เป็นเวลา 12 สัปดาห์ ทำการวัดวิเคราะห์ปัจจัยต่าง ๆ ได้แก่ การหายใจแบบหูฟริ้น ระยะทางที่เดินได้ภายในเวลา 6 นาที สมรรถภาพของปอด และความแข็งแรงกล้ามเนื้อหายใจโดยใช้กังหันลม

ผลการศึกษา: ภายหลัง 12 สัปดาห์ กลุ่มการหายใจแบบหูฟริ้นโดยใช้กังหันลมของเล่นมีการมีการหายใจเข้าและออกในมิติการต่าง ๆ ได้รับประโยชน์กลุ่ม ได้แก่ จำนวนการหายใจที่รวดเร็ว ที่มีการเปลี่ยนแปลงของความจุปอดและการหายใจออกใน 1 วินาที สูงขึ้น และมีความแข็งแรงกล้ามเนื้อหายใจผู้สูงอายุขึ้นอย่างมีนัยสำคัญทางสถิติที่ระดับ 0.05 เมื่อเทียบกับกลุ่มควบคุมและกลุ่มการหายใจแบบใช้กะบังลม อย่างไรก็ตาม ไม่มีการเปลี่ยนแปลงของความแข็งแรงของกล้ามเนื้อหายใจออกใน 1 วินาที 3 กลุ่มการทดลอง

สรุป: การหายใจแบบหูฟริ้นโดยใช้กังหันลมของเล่นเป็นกรัฎการหายใจที่มีประสิทธิภาพสูงขึ้นผู้สูงอายุ โดยช่วยให้สมรรถภาพของปอดและความแข็งแรงของกล้ามเนื้อหายใจในผู้สูงอายุเพิ่มขึ้น