DOI: 10.5114/areh.2023.125825
Original article Advances in Rehabilitation, 2023, 37(1), 23–32

A – Research concept and design
B – Collection and/or assembly of data
C – Data analysis and interpretation
D – Writing the article
E – Critical revision of the article
F – Final approval of article

Received: 2022-12-12
Accepted: 2023-03-11
Published: 2023-03-13

Pilot study on improvement in respiratory function in sedentary young female adults with forward shoulder posture following scapulothoracic exercises: a randomized controlled trial

Kanogwun Thongchote[1,A-F], Khomchan Threetepchanchai[1,B,E-F], Artima Chuwijit[1,B,E-F], Sarawut Lapmanee*[2,A-F]

[1]Department of Physical Therapy, Faculty of Physical Therapy, Srinakharinwirot University, Thailand
[2]Department of Basic Medical Sciences, Faculty of Medicine, Siam University, Thailand

Corresponding author: Sarawut Lapmanee; Department of Basic Medical Sciences, Faculty of Medicine, Siam University, Thailand; email: sarawut.lap@siam.edu

Abstract

Introduction: Upper body muscular imbalance is a potential risk factor in various shoulder problems and respiratory functions. Exercises aimed at the pectoralis minor and scapular stabilizer muscles could alleviate muscular imbalances in forward shoulder posture (FSP). However, the efficacy of these exercises on respiratory function, including chest mobility, lung capacity, and respiratory muscle strength in FSP remains unclear.

Material and methods: In this randomized clinical trial, 28 female participants with FSP, aged 18–23 years, were divided into the control and exercise groups. The exercise programs were conducted five days/week for eight weeks. The distance from the acromion process to the wall was measured to determine FSP. Pectoralis minor length (PL) were measured from coracoid process to the fourth costosternal joint, thoracic kyphosis (TK) was measured along the thoracic spines, chest expansion was measured from the amplitude of thoracic wall circumference during full expiration and inspiration, maximal respiratory muscle strength generated during respiration (MIP), and maximum respiratory muscle strength during expiration (MEP); all were assessed pre- and post-exercise intervention.

Results: After the eight-week training program, an improvement in FSP was observed, manifested as decreased mean difference ($p < 0.05$) and TK ($p < 0.003$). The PL ($p < 0.05$) and lower part of chest expansion ($p < 0.010$) were restored compared to the control group. The strength generated in respiration (MIP) also improved in the exercise group ($p < 0.013$).

Conclusions: An eight-week pectoral muscle stretching and scapular stabilizer strengthening programme could reduce FSP, improving chest mobility and respiratory muscle strength.

Keywords: forced vital capacity, maximum inspiratory pressure, rounded shoulder, strengthening exercises, thoracic excursion

Introduction

Habitual poor posture in everyday tasks might cause upper body muscular imbalance, which is a potential risk factor in various shoulder problems and respiratory functions [1,2]. Forward shoulder posture (FSP) is a postural misalignment resulting from a muscular imbalance between agonists and antagonists, namely a tightness of the anterior shoulder girdle muscles, predominantly the pectoralis minor, and weakness of the scapular muscles, especially the lower trapezius and serratus anterior [3,4]. Several studies have reported the occurrence of postural defects among college-age female students [5–8]. Any imbalance between these muscles subsequently alters the scapular position, causing abnormal protraction, downward rotation, and anterior tipping, which makes the shoulder move anteriorly [9,10]. In addition, FSP progressively develops into a slumped position characterized by an increase in a forward head posture and thoracic kyphosis (TK), thus resulting in dyspnea and respiratory dysfunction [11–13]. These slumped sitting postures increase the proximity of the ribs to the pelvis and intra-abdominal pressure limiting the movement of the diaphragm during inspiration [13,14].

Collectively, poor posture due to FSP leads not only to orthopedic problems but also a deterioration in the respiratory system. Tightness in the anterior shoulder girdle muscles, especially the pectoral muscles, limits chest wall movement in inspiration leading to increased work of breathing and decreased exercise capacity [15,16]. Impairment of pulmonary function has been found to be associated with decreased pectoralis minor muscle length and an increased degree of FSP in chronic obstructive pulmonary disease patients [17]. A previous study indicated a correlation between elevated FSP and diminished pulmonary capacity, i.e., vital capacity, forced vital capacity (FVC), and expiratory residual volume [18], and that treatment alleviating FSP was an essential component of a rehabilitation program to prevent shoulder injuries and improve respiratory efficiency [18,19].

One effective approach for correcting muscular imbalance would be to stretch the tight muscles and strengthen the weak ones, [12]. Interestingly, many studies have reported that the combined stretching of pectoralis minor muscles and the strengthening of the scapular stabilizer muscles alleviated muscular imbalance in individuals with FSP [19–22]. However, the effects of combined exercise interventions on the respiratory muscle strength and parameters of pulmonary function still remain unclear. Therefore, this study aimed to determine the effects of combined pectoral muscle stretching and scapular stabilizer strengthening exercises on the respiratory functions in female subjects with FSP. We hypothesized that the exercise regimen could alleviate FSP, minimizing the limitation of respiratory muscle strength and functions.

Materials and methods

Study design

The study was designed as a randomized, controlled clinical trial. Ethics approval was conducted by the Ethical Committee from the Faculty of Physical Therapy, Srinakharinwirot University, Thailand (PTPT2016-007). The trial was also registered under the Thai Clinical Trial Registry, registration number TCTR 20180622002.

Participants

Sedentary female participants were recruited from Srinakharinwirot University. The necessary sample size was calculated using the G-power program, version 3.1.9.2 (University of Kiel, Kiel, Germany) [23]. ANOVA with repeated measures and within-between group interaction was used; this approach yielded a statistical power of 0.8, an α error probability of 0.05, and an effect size of 0.68.

Based on the calculation, the required minimum sample size was 12 participants per group. However, assuming that 10% would drop out equally, two additional participants were added per group. Therefore, the present study enrolled 28 female participants, i.e. two groups of 14, with a mean age of 20.00 ± 1.40 years and body mass index (BMI) of 20.10 ± 1.60 kg/m^2. The 28 eligible participants were randomly allocated into two groups, i.e., the control ($n = 14$) and exercise groups ($n = 14$) (Fig. 1). The inclusion criteria of participation comprised females sex, FSP, healthy BMI (18.50-24.90 kg/m^2), and no underlying diseases [24,25]. The shoulder posture was considered forward if the distance from the acromial head to the wall was greater than 2.54 cm [13,21]. The exclusion criteria comprised a history of chronic neck or shoulder pain with a pain scale of more than three evaluated by visual analogue scale (VAS), cardiopulmonary problems and refusal to participate [4,26,27].

Randomization and blinding

After baseline assessment, the participants were assigned to study groups at random by computer. The exercise group participated in the training program for eight weeks, in line with previous studies [28–30]. The control group received no exercise training but was educated on FSP management, i.e., postural awareness. The outcomes at baseline and week 8 (post-exercise) were blinded to the group allocation. The personal information received from the statistical analyses was blinded to the interventions, which were identified by a numerical code.

Procedure

The main outcomes, including forward shoulder posture, pectoralis minor length, thoracic kyphosis, chest expansion, maximum pressure generated in respiration, and forced vital capacity were assessed using procedures documented previously from the current study [31].

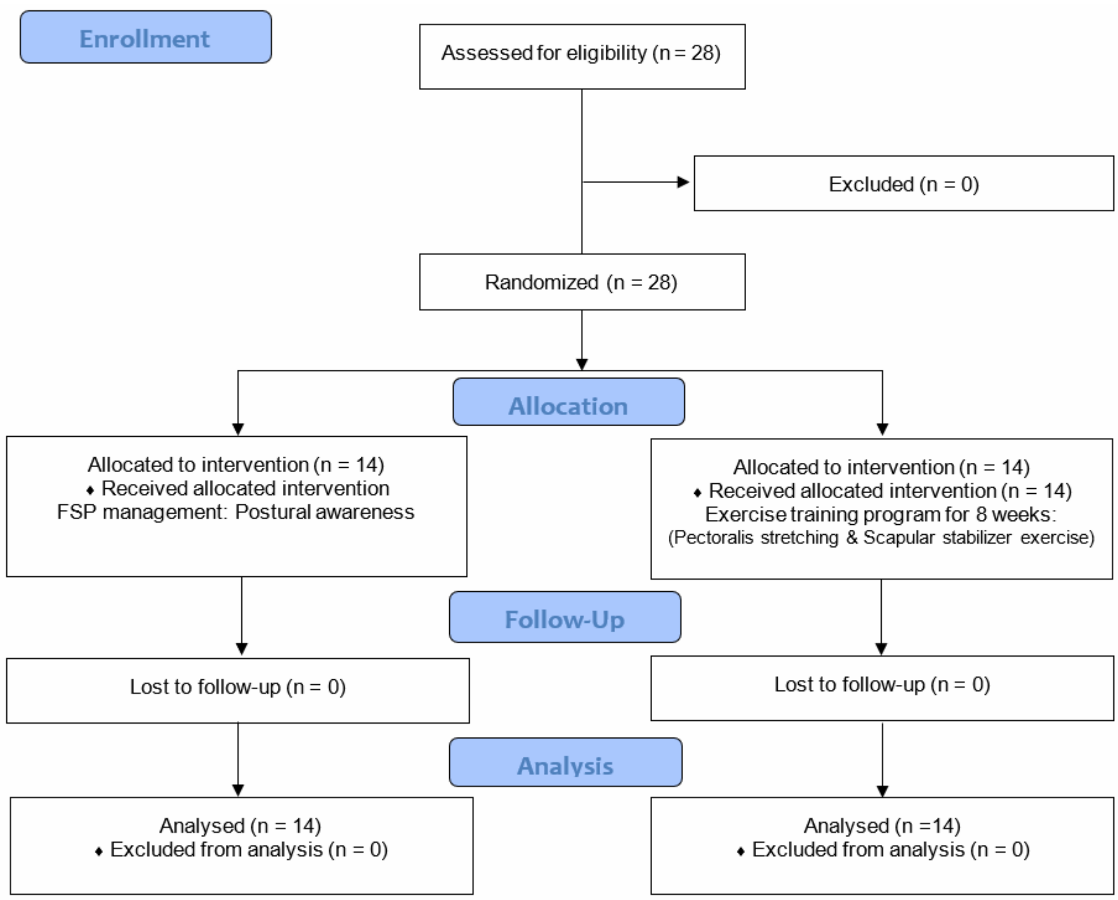

Fig. 1. Diagram CONSORT 2010 flowchart of participation process in the study

Measurements of the forward shoulder posture (FSP)

The magnitude of FSP was assessed using a vernier height gauge (Mitutoyo 506-207, Japan) with a range of 0-200-mm, resolution of 0.02-mm, and accuracy of 0.03-mm. The magnitude of FSP in millimeters was determined by measuring the distance from the wall to the anterior aspect of the acromion process. The base of the vernier height gauge was located on the wall; consequently, the tip of the instrument was moved and placed on a marker at the anterior tip of the acromion process. The FSP was assessed in a relaxed position [31,32].

Measurements of pectoralis minor length (PL)

The left and right PL were measured by a vernier caliper (530-101 series, Mitutoyo, Japan) with a range of 0-150-mm and 0.05-mm accuracy. In a relaxed sitting position, markings were made on the inferior angle of the coracoid process and the fourth costosternal junctions on both the left and right sides [20,31,33]. The distance between these markers was measured three times in millimeters on each side.

Measurements of thoracic kyphosis (TK)

The TK was evaluated using a flexible ruler. In the standing position, the spinous process of the seventh cervical vertebra and the twelfth thoracic vertebra were marked on the volunteer's skin. At this point, the flexible ruler was curved along the thoracic spine and the flexicurve method was used to calculate the thoracic angle [31,34–36].

Measurements of chest expansion

Chest expansion was based on the difference in the thoracic wall size between full expiration and inspiration [31,37]. A measuring tape was fitted around each landmark to measure each level of the chest expansion in centimeters. Each participant was verbally instructed to exhale and then inhale. Three levels of chest wall circumference, the upper, middle, and lower chest, were determined with apparent landmarks on the subject's skin. For the upper chest area, the fifth thoracic spinous process (T5) and the third intercostal space were marked at the mid-clavicular line. For the middle chest area, the seventh thoracic spinous process (T7) and the fifth intercostal space at the mid-clavicular line were marked. For the lower chest area, the tenth thoracic spinous process (T10) and the tip of the xiphoid process were measured [31,38].

Measurements of maximum pressure generated in inspiration (MIP), and expiration (MEP)

The strength of respiratory muscles was determined by measuring MIP and MEP as centimeter water pressure (cmH_2O). The evaluation was conducted in accordance with the criteria and procedures established by the American Thoracic Society/European Respiratory Society (ATS/ESR) [31,39]. A respiratory pressure meter (Micro RMA, Micro Medical Ltd., UK) was used to record the pressure at the mouth during maximal inspiration and expiration. The participants were generally recorded in a sitting position with a nose clip. MIP was recorded during the maximal inspired maneuver from the residual volume, and MEP during the Valsalva maneuver of the maximal expiration from the total lung capacity. The measurement was performed for at least three maneuvers with the range of 5–10% reproducibility [40].

Measurements of forced vital capacity (FVC)

According to the ATS/ESR guidelines, spirometry testing was performed to determine the lung volume in litres as an FVC value. In the sitting position, the volunteers were instructed to inhale deeply and forcefully exhale through a spirometer (Viasys Micro Lab 3500, UK). The acceptable repeatability of each FVC maneuver followed the criteria of the ATS/ESR guidelines [41].

Intervention

The volunteers in the exercise group performed exercises to stretch the pectoral muscle then strengthen of the lower trapezius and serratus anterior muscles five days a week for eight weeks [20].

Pectoralis stretching exercise

During the stretching exercise, the participants stood in the corner with their foot positioned behind the labeled line. The shoulder was externally rotated and abducted at 90° and 120° with elbow flexion at a starting position. One by one, the participant was instructed to actively stretch the pectoral muscle by rotating the central part of the body to the opposite side until reaching the end feel for 10 sequential repetitions/day; each stretch was held for 10 seconds, with a 30 second break between each stretch [19].

Lower trapezius and serratus anterior strengthening exercise

To strengthen the lower trapezius, a prone V-raise position was performed with a 125° shoulder horizontal abduction, flexed elbow for the first six weeks, then the difficulty was increased with an extended elbow for the last two weeks. The participant was guided to elevate both arms until the end range of the 10 repetitions/set, three sets/day, and was allowed a 30 second break between each set. Push-ups on the wall or standard push-ups on a stability chair support were performed to strengthen the serratus anterior [41]. A chair of standardized height (48–49 cm) was used in all sessions. Push-ups were performed on the wall from weeks 1 to 6, and then on a stability chair support with the feet on the floor in weeks 7 and 8. The participant was instructed to maintain that posture while performing the push-up position. The subject moved the shoulders forward to promote scapular protraction and then backward to perform scapular retraction for three sets of 10 repetitions with a 30 second break between the sets [10,22].

Statistical analysis

The results were organized and analyzed by IBM SPSS software, version 23 (IBM Corp., USA). The Shapiro-Wilk test was used to confirm a normal distribution, and parametric tests were used for analyses. The characteristics of the participants at the baseline are expressed as mean ± SD, and the mean differences of the pre- and post-tests between the control and exercise groups were compared with the independent t-test. The significance level for the statistical test was set as $p < 0.05$.

Results

In terms of quality control, all measuring devices were reliably calibrated by experienced technicians before starting the experiment. The intra-class correlation coefficient ($ICC_{2,1}$) was calculated from the two compared measurements. In this study, all parameters demonstrated an ICC between 0.92 and 0.99, indicating very good reliability ($p < 0.001$). The study was carried out with 28 participants, 14 in each group. The baseline personal profiles of the participants are presented in Table 1. No significant difference was observed in the baseline, which represented the identical characteristics between the two groups.

Effect of exercise-induced FSP reduction on TK and PL

The structural alterations of FSP, TK, and PL are shown in Figure 2. The mean differences in FSP (left side, $p = 0.007$; right side, $p = 0.026$) and TK ($p = 0.003$) were significantly reduced in the exercise group when compared to controls (Fig. 2A-B). Moreover, the exercise group demonstrated a greater mean difference in

Tab. 1. Baseline characteristics of all participants

	Control group	Exercise group	p-value
	Means ± SD	Means ± SD	
Age (years)	20.00 ± 1.60	20.00 ± 1.10	0.18
Height (cm)	160.00 ± 6.90	161.00 ± 4.70	0.70
Weight (kg)	52.90 ± 7.10	50.80 ± 5.60	0.39
Body mass index (kg/m^2)	20.70 ± 0.40	19.60 ± 1.50	0.09
Forward shoulder posture (cm)	6.20 ± 1.10	6.90 ± 0.90	0.07
Pectoralis minor length (cm)	16.0 ± 14.10	16.10 ± 9.30	0.77
Chest expansion (cm)	5.90 ± 1.00	5.80 ± 1.00	0.93
Force vital capacity (mL)	2.90 ± 0.30	2.90 ± 0.20	0.79
MIP (cmH_2O)	78.00 ± 4.50	78.40 ± 5.50	0.95
MEP (cmH_2O)	84.30 ± 18.50	86.10 ± 17.50	0.79

cm − centimeter, cmH_2O − centimeter of water, kg − kilogram, kg/m^2 − kilogram per square meter, MEP − maximum expiratory pressure, MIP − maximum inspiratory pressure, mL − milliliter.

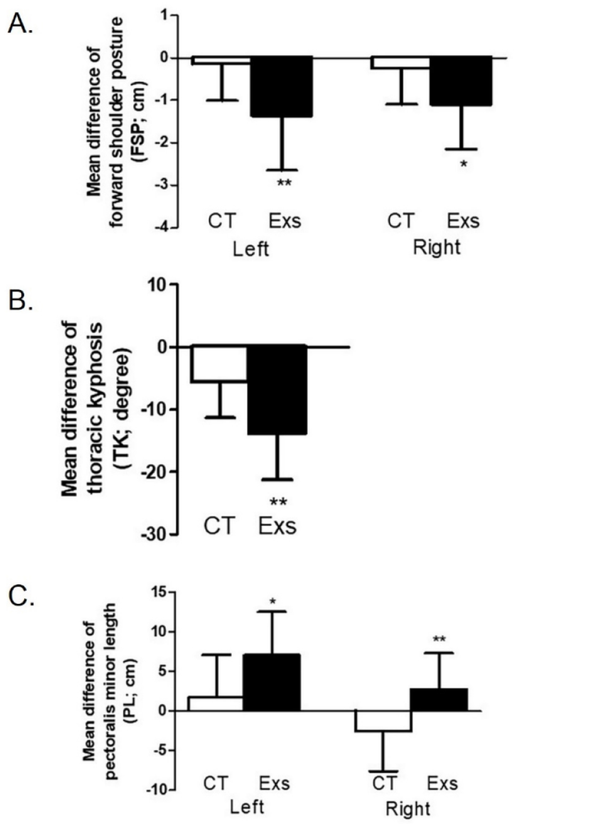

Fig. 2. Changes in forward shoulder posture. (A) Mean difference of forward shoulder posture (FSP; cm), (B) Thoracic kyphosis (TK; degree), and (C) Pectoralis minor muscle length (PL; mm) after the eight-week exercise training in the control (CT) and exercise groups (Exs).*p < 0.05 , **p < 0.01 compared to control group

PL than the controls (left side, p = 0.014; right side, p = 0.008) (Fig. 2C). These results suggest that the employed eight-week exercise training program combining pectoral muscle stretching and scapular stabilizer strengthening could alleviate the FSP and the degree of TK, accompanied by an increase in PL.

Effect of exercise-induced FSP reduction on chest mobility and respiratory muscle strength

Regarding the three parts of the chest expansion (Fig. 3A-C), the exercise-trained group showed a greater difference in chest expansion during the intervention compared to controls. Therefore, the eight-week exercise program aimed at reducing FSP alleviated the restriction in the lower part of the chest (p = 0.010) (Fig. 3C), but not in the upper (p = 0.813) (Fig. 3A) or middle (p = 0.912) (Fig. 3B) parts.

Effect of exercise-induced FSP reduction on respiratory muscle strength and lung capacity

A significantly greater increase in inspiratory muscle strength, measured by MIP (Fig. 4A) was noted in the exercise group than controls (p = 0.013). The mean difference of MIP in the control group was 3.71 ± 2.84 cmH_2O and 15.29 ± 3.27 cmH_2O in the exercise-trained group. In contrast, no significant difference in expiratory muscle strength as measured by MEP (Fig. 4B) was found between the groups (p = 0.433). This indicates that the improvement in FSP resulting from the eight-week exercise training program could create greater force during

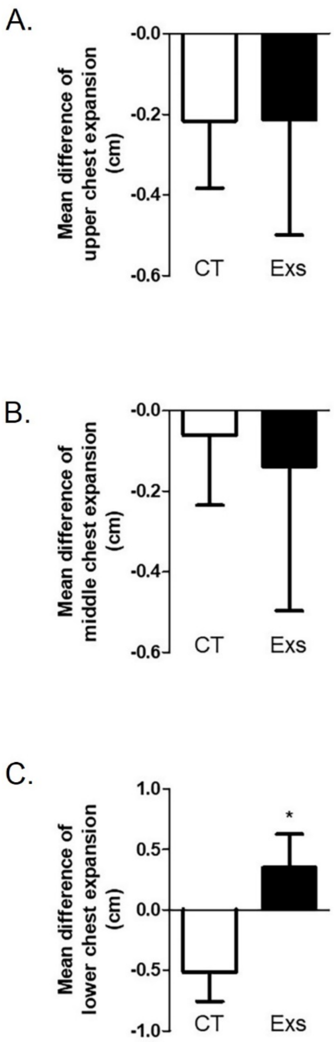

Fig. 3. Changes in chest expansion. (A) Mean difference of upper chest , (B) middle chest, and (C) lower chest expansion in control (CT) and exercise group (Exs) after the eight weeks of exercise training for reducing forward shoulder posture

*p <0.05 compared to control group

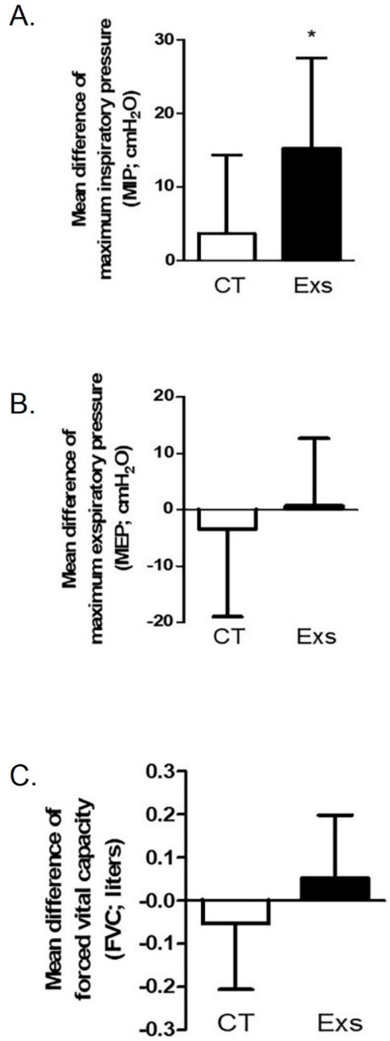

Fig. 4. Changes in maximum inspiratory pressure. (A) Mean difference of Maximum inspiratory pressure (MIP; cmH_2O), (B) Maximum expiratory pressure (MEP; cmH_2O), and (C) Forced vital capacity (FVC; liter) in control (CT) and exercise group (Exs) after the eight weeks of exercise training for reducing forward shoulder posture

*p < 0.05 compared to control group

inspiration. In addition, the exercise-trained group showed a small increase in FVC (Fig. 4C), when compared to the control, but this difference was not significant ($p = 0.072$); however, this nonetheless indicates an improvement in lung capacity during the eight-week exercise programme aimed at reducing FSP.

Discussion

Muscular imbalance resulting from poor posture has a strong influence on postural misalignments, including FSP, and the development of musculoskeletal and respiratory problems [1,2,43]. Tightness in the pectoral muscle and weakness in the scapular stabilizer, particularly the lower trapezius and serratus anterior, are major characteristics of upper quadrant muscular dysfunction in FSP [3,4,9]. These imbalances subsequently lead to an abnormal plane of scapular movements, including anterior tipping, internal rotation, and downward rotation [9,17,39]. The findings of this study indicate that the employed exercise program, comprising pectoral muscle stretching and scapular stabilizer muscle strengthening for eight weeks (five days/week) could reduce FSP, manifested as increased pectoralis minor length (PL) and decreased thoracic kyphosis (TK). In addition, the reduction of FSP led to an improvement in inspiratory muscle strength and chest expansion.

The selected exercise interventions were chosen due to their ability to stretch the tightened muscles and strengthen the weak muscles in the FSP [2,3]. The results were consistent with previous findings confirming a reduction in FSP with muscular imbalance. Similarly, a six-week programme of combined manual treatment and stabilizing exercises was found to improve function and posture in women with forward head and rounded shoulder postures [44]. As compared to conventional physiotherapy treatment, six-week scapular stabilization exercise promoted postural adjustment and relieved neck pain more effectively among female patients [45].

A two-week pectoral muscle stretching program was found to improve the scapular position and decrease FSP [3]. Moreover, a six-week programme comprising anterior shoulder stretching and posterior shoulder strengthening was able to reduce FSP in competitive swimmers [32]. In addition, a unilateral corner self-stretch of the pectoral muscles at 90° shoulder abduction produced the greatest length change in the pectoralis minor muscle and maximally reduced FSP [9]. Hence, it was likely that a reduction in FSP would be related to an increase in PL.

During static stretching, an increase in the pectoral muscle tension would activate the Golgi tendon organ, temporarily inhibiting muscle spindle activity. Hence, reduced tension in the pectoral muscles would further relax them to increase their lengths and reduce FSP [15].

The agonist muscles, i.e. the scapular stabilizers, particularly the lower trapezius and serratus anterior, was used to counteract the weakness and loss of movement associated with the muscular imbalance in FSP [46]. When the agonist muscles contracted, the tension in the antagonist muscle (pectorals) was inhibited by impulse signals from the motor neurons, thus relaxing them [15, 46]. The strength of the agonist muscle groups enhanced scapular retraction, upward rotation and posterior tilting, thus restoring the scapular plane in FSP [47]. Additionally, a six-week pectoral muscle stretching and scapular retractor and elevator strengthening programme was found to promote scapular stability [48]. Furthermore, it appears that the use of scapular stabilization exercise following pectoralis muscle stretching could decrease FSP and increase the pectoralis minor index [28]. In addition, electromyography (EMG) data found this combined intervention to be the most effective treatment for improving lower trapezius muscle activity [22]. These findings clearly support the effectiveness of the present exercise training program in reducing FSP. It would, however, be beneficial to complete further studies with EMG measurements to confirm the muscle activities.

The present study was the first to assess the effects of stretching and strengthening exercise on respiratory functions of subjects with FSP. By reducing the degree of TK in participants with FSP, the intervention corrected the muscular imbalance and improved posture. This finding is in line with previous findings regarding the prevalence of TK accompanying FSP in individuals [41]. In FSP, the subacromial space narrowed in the presence of thoracic hyperkyphosis, due to the shoulder muscle imbalance, and was also associated with the degree of TK and scapular protraction [49].

TK associated with dyspnea and respiratory dysfunction has been observed in older people [13,50]. Additionally, the adoption of a slumped sitting posture results in the shifting of the ribs and the pelvis, which increased intra-abdominal tension and prevented the diaphragm from descending caudally [10]. Moreover, the lengths of the intercostal muscles become impaired, thus making it difficult for them to contract and relax during respiration. Therefore, reducing FSP and the degree of TK made the upper trunk more erect and improved thoracic cage compliance [17]. Thereafter, the diaphragm, attached to the lower edge of the chest, functioned more effectively to expand the chest, as shown by the MIP [51].

However, no changes in the MEP were observed in the present study. Normally, forced expiration would be important for coughing and secretion clearance, which would be created by the maximum contraction of the abdominal muscles [52]. However, the exercise programme employed in the present study might be unrelated to abdominal muscle recruitment.

Regarding lung capacity, a combination of therapeutic exercises, including scapular stabilization, was found to improve thoracic mobility and forced expiratory volume at one second (FEV1), but not FVC [53]. Similarly, it was found that although a prescribed FSP exercise program resulted in no significant difference in FVC, it tended to delay the age-related reduction in FVC [54].

Another limitation is that the study only includes healthy female subjects; as such this may limit the generalisability of its findings to male subjects. Therefore, further investigation is still needed in this area.

Conclusions

The tested eight-week programme of pectoral muscle stretching and scapular stabilizer strengthening exercises could alleviate FSP, resulting in improved TK, chest expansion and inspiratory muscle strength in sedentary participants. As mentioned previously, these exercise interventions are cost effective and could be applied to prevent and alleviate poor posture and muscular imbalance in both a healthy population and in individuals with pulmonary diseases. Additionally, the exercise regimen will be tested in patients presenting with mild to moderate chronic obstructive pulmonary disease (COPD) in a later study.

Acknowledgments
The authors would like to thank Assistant Professor Dr. Kukiat Tudpor, Faculty of Public Health, Maha Sarakham University for English editing and proofreading in the first draft of the manuscript and financial support for publication from Faculty of Medicine, Siam University.

Funding
This research received no external funding.

Conflicts of Interest
The authors have no conflict of interest to declare.

References

1. Jung SI, Lee NK, Kang KW, Kim K, Lee DY. The effect of smartphone usage time on posture and respiratory function. J Phys Ther Sci. 2016; 28: 186–9.
2. Kang KW, Jung SI, Lee do Y, Kim K, Lee NK. Effect of sitting posture on respiratory function while using a smartphone. J Phys Ther Sci. 2016; 28(5):1496–8.
3. Kinney E, Wusthoff J, Zyck A, Hatzel B, Vaughn D, Strickler T, et al. Activation of the trapezius muscle during varied forms of Kendall exercises. Phys Ther Sport. 2008; 9: 3–8.
4. Kim MK, Lee JC, Yoo KT. The effects of shoulder stabilization exercises and pectoralis minor stretching on balance and maximal shoulder muscle strength of healthy young adults with round shoulder posture. J Phys Ther Sci. 2018; 30(3): 373–80.
5. Shah S, Patil PH. Effect of posture correction and moderate-intensity exercises on respiratory system in teenagers. Indian J Med Sci. 2019; 71(3): 113−7.
6. Ghanbari A, Ghaffarinejad F, Mohammadi F, Khorrami M, Sobhani S. Effect of forward shoulder posture on pulmonary capacities of women. Br J Sports Med. 2008; 42(7): 622–3.
7. Maekawa M, Yoshizawa E, Hayata G, Ohashi S. Physical and psychological effects of postural educational intervention for students experienced school refusal. Curr Psychol. 2021.
8. Kiruthika S, Rekha K, Preethy G, Abraham M. Prevalence of Postural Dysfunction among Female College Students – A Qualitative Analysis. Biol Med. 2017; 10(1): 1000421.
9. Borstad JD, Ludewig PM. Comparison of three stretches for the pectoralis minor muscle. J Shoulder Elb Surg. 2006; 15: 324–30.
10. Takeno K, Glaviano NR, Norte GE, Ingersoll CD. Therapeutic interventions for scapular kinematics and disability in patients with subacromial impingement: A systematic review. J Athl Train. 2019; 54(3): 283–95.
11. Morais N, Cruz J. The pectoralis minor muscle and shoulder movement-related impairments and pain: Rationale, assessment and management. Phys Ther Sport. 2016; 17: 1–13.
12. Sahrmann S, Azevedo DC, Dillen LV. Diagnosis and treatment of movement system impairment syndromes. Braz J Phys Ther. 2017; 21(6): 391–9.
13. Di Bari M, Chiarlone M, Matteuzzi D, Zacchei S, Pozzi C, Bellia V, et al. Thoracic kyphosis and ventilatory dysfunction in unselected older persons: an epidemiological study in Dicomano, Italy. J Am Geriatr Soc. 2004; 52: 909–15.
14. Lin F, Parthasarathy S, Taylor SJ, Pucci D, Hendrix RW, Makhsous M. Effect of different sitting postures on lung capacity, expiratory flow, and lumbar lordosis. Arch Phys Med Rehabil. 2006; 87: 504–9.
15. Putt MT, Watson M, Seale H, Paratz JD. Muscle stretching technique increases vital capacity and range of motion in patients with chronic obstructive pulmonary disease. Arch Phys Med Rehab. 2008; 89: 1103–7.
16. Cavalcanti JD, Fregonezi GAF, Sarmento AJ, Bezerra T, Gualdi LP, Pennati F, Aliverti A, Resqueti VR. Electrical activity and fatigue of respiratory and locomotor muscles in obstructive respiratory diseases during field walking test. PLoS One. 2022; 17(4): e0266365.
17. Morais N, Cruz J, Marques A. Posture and mobility of the upper body quadrant and pulmonary function in COPD: an exploratory study. Braz J Phys Ther. 2016; 20: 345–54.
18. Ghanbari A, Ghaffarinejad F, Mohammadi F, Khorrami M, Sobhani S. Effect of forward shoulder posture on pulmonary capacities of women. Br J Sports Med. 2008; 42: 622–3.
19. Dias CS, Kirkwood RS, Parreira VF, Sampaio RF. Orientation and position of the scapula, head and kyphosis thoracic in male patients with COPD. Can J Respir Ther. 2009; 45: 30–4.
20. Lee JH, Cynn HS, Yoon TL, Ko CH, Choi WJ, Choi SA, et al. The effect of scapular posterior tilt exercise, pectoralis minor stretching, and shoulder brace on scapular alignment and muscles activity in subjects with round-shoulder posture. J Electromyogr Kinesiol. 2015; 25(1): 107–14.
21. Wong CK, Coleman D, diPersia V, Song J, Wright D. The effects of manual treatment on rounded-shoulder posture, and associated muscle strength. J Bodyw Mov Ther. 2010; 14: 326–33.

22. Cappato de Araújo R, Andrade da Silva H, Pereira Dos Passos MH, Alves de Oliveira VM, Rodarti Pitangui AC. Use of unstable exercises in periscapular muscle activity: A systematic review and meta-analysis of electromyographic studies. J Bodyw Mov Ther. 2021; 26: 318–28.
23. Gaude GS, Savadatti R, Hattiholi J. Postural correction for kyphosis improves the dyspnea index and pulmonary functions in patients with chronic obstructive pulmonary disease: A randomized trial over 12 weeks. Int J Health Allied Sci. 2014; 3: 44–5.
24. Lutfi MF. The physiological basis and clinical significance of lung volume measurements. Multidiscip Respir Med. 2017; 12: 3.
25. Magee D. Orthopedic physical assessment. 5th Edition, Saunders, Toronto. 2008.
26. Boonstra AM, Stewart RE, Köke AJ, Oosterwijk RF, Swaan JL, Schreurs KM, et al. Cut-off points for mild, moderate, and severe pain on the numeric rating scale for pain in patients with chronic musculoskeletal pain: variability and influence of sex and catastrophizing. Front Psychol. 2016; 7: 1–9.
27. Yoo WG. Comparison of the effects of pectoralis muscles stretching exercise and scapular retraction strengthening exercise on forward shoulder. J Phys Ther Sci 2018; 30(4): 584–5.
28. Lee DY, Nam CW, Sung YB, Kim K, Lee HY. Changes in rounded shoulder posture and forward head postbbure according to exercise methods. J Phys Ther Sci. 2017; 29(10): 1824–7.
29. Abdolahzadeh M, Daneshmandi H. The effect of an 8-week NASM corrective exercise program on upper crossed syndrome. J Sport Biomech. 2019; 5 (3):156–67.
30. Mogharrabi-Manzari M, Ghasemi G, Negahban H. The effect of eight-week shoulder girdle, pelvic girdle and combined corrective exercises on maximal voluntary ventilation in female students with upper crossed syndrome: a randomized clinical trial. J Rehabil Sci. 2021; 8(2): 51–6.
31. Thongchote K, Sangchuchuenjit C , Vichaichotikul W , Choosaranon N , Kulsiri N, Lopansri P, et al. The functional correction of forward shoulder posture with kinesiotape improves chest mobility and inspiratory muscle strength: A randomized controlled trial. Ann Appl Sport Sci. 2022: 2476–4981.
32. Kluemper M, Uhl T, Hazelrigg H. Effect of stretching and strengthening shoulder muscles on forward shoulder posture in competitive swimmers. J Sport Rehabil. 2006; 15: 58–70.
33. Borstad JD. Measurement of pectoralis minor muscle length: validation and clinical application. J Orthop Sports Phys Ther. 2008; 38(4): 169–74.
34. Fa T, Ga C. Reliability and validity of thoracic kyphosis measurements using the flexicurve method. Rev bras fisioter. 2007; 11(3): 173–7.
35. Ohrt-Nissen S, Cheung JPY, Hallager DW, Gehrchen M, Kwan K, Dahl B, et al. Reproducibility of thoracic kyphosis measurements in patients with adolescent idiopathic scoliosis. Scoliosis Spinal Disord. 2017; 12: 4.
36. Bockenhauer SE, Chen H, Julliard KN, Weedon J. Measuring thoracic excursion: reliability of the cloth tape measure technique. J Am Osteopath Assoc. 2007; 107(5): 191–6.
37. Moeliono M, Sari DM, Nashrulloh T. Prediction for the maximum inspiratory pressure value from the thoracic expansion measurement in Indonesian healthy young adults. Can J Respir Ther. 2022; 58: 34–8.
38. Tantisuwat A, Thaveeratitham P. Effects of smoking on chest expansion, lung function, and respiratory muscle strength of youths. J Phys Ther Sci. 2014; 26(2): 167–70.
39. Laveneziana P, Albuquerque A, Aliverti A, Babb T, Barreiro E, Dres M, et al. ERS statement on respiratory muscle testing at rest and during exercise. Eur Respir J. 2019; 53(6): 1801214.
40. Troosters T, Gosselink R. Decrame M. Respiratory muscle assessment. Eur Respir Mon. 2005; 31: 57–71.
41. Miller MR, Hankinson J, Brusasco V, Burgos F, Casaburi R, Coates A, et al. Standardisation of spirometry. Eur Respir J. 2005; 26(2): 319–38.
42. Nejati P, Lotfian S, Moezy A, Moezy A, Nejati M. The relationship of forward head posture and rounded shoulders with neck pain in Iranian office workers. Med J Islam Repub Iran. 2014; 28: 1–7.
43. Phadke V, Camargo P, Ludewig P. Scapular and rotator cuff muscle activity during arm elevation: A review of normal function and alterations with shoulder impingement. Rev Bras Fisioter. 2009; 13(1): 1–9.
44. Fathollahnejad K, Letafatkar A, Hadadnezhad M. The effect of manual therapy and stabilizing exercises on forward head and rounded shoulder postures: a six-week intervention with a one-month follow-up study. BMC Musculoskelet Disord. 2019; 20(1): 86.
45. El Gendy MH, Wadee Mawad AN, Mostafa YS. Scapular stabilization exercise versus neck stabilization exercise in females with chronic mechanical neck pain. Med J Cairo Univ. 2021; 89(7): 2729–34.
46. Tsuruike M, Ellenbecker TS. Serratus anterior and lower trapezius muscle activities during multi-joint isotonic scapular exercises and isometric contractions. J Athl Train. 2015; 50(2): 199–210.
47. Ruivo RM, Pezarat-Correia P, Carita AI. Intrarater and interrater reliability of photographic measure-

ment of upper-body standing posture of adolescents. J Manipulative Physiol Ther. 2015; 38(1): 74–80.
48. Hibberd EE, Oyama S, Spang JT, Prentice W, Myers JB. Effect of a 6-week strengthening program on shoulder and scapular-stabilizer strength and scapular kinematics in division I collegiate swimmers. J Sport Rehabil. 2012; 21(3): 253–65.
49. Cheshomi S, Rajabi R. The relationship between thoracic kyphosis curvature, scapular position and posterior shoulder girdle muscles endurance. World Appl Sci J. 2011; 14: 1072–6.
50. Scarlata S, Pedone C, Fimognari FL, Bellia V, Forastiere F, Incalzi RA. Restrictive pulmonary dysfunction at spirometry and mortality in the elderly. Respir Med. 2008; 102(9): 1349–54.
51. Kim CB, Yang JM, Choi JD. The effects of chest expansion resistance exercise on chest expansion and maximal respiratory pressure in elderly with inspiratory muscle weakness. J Phys Ther Sci. 2015; 27(4): 1121–4.
52. Zach MS, Oberwaldner B. Chapter 18 – Chest Physiotherapy. In: Taussig LM, Landau LI (eds). Paediatric Respiratory Medicine 2nd ed. St Louis: Mosby Inc.; 2008.
53. Kang NY, Im SC, Kim K. Effects of a combination of scapular stabilization and thoracic extension exercises for office workers with forward head posture on the craniovertebral angle, respiration, pain, and disability: A randomized-controlled trial. Turk J Phys Med Rehabil. 2021; 67(3): 291–9.
54. Burtscher J, Millet GP, Gatterer H, Vonbank K, Burtscher M. Does regular physical activity mitigate the age-associated decline in pulmonary function? Sports Med. 2022; 52(5): 963–70.