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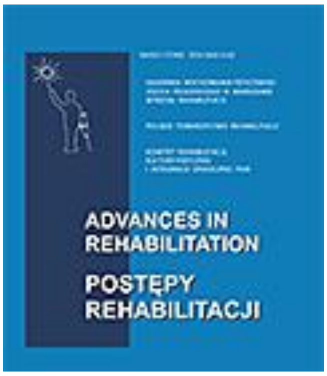

Review article

Title: Pilot study on the improvement effects of scapulothoracic exercises on the respiratory functions in sedentary young female adult with forward shoulder posture: a randomized control trial

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Pilot study on the improvement effects of scapulothoracic exercises on the respiratory functions in sedentary young female adult with forward shoulder posture: a randomized control trial

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Abstract

Introduction: Upper body muscular imbalance is a potential risk of various shoulder problems and respiratory functions. The combined pectoralis minor muscles and scapular stabilizer muscles could alleviate muscular imbalances in forward shoulder posture (FSP). However, there remains an unclear conclusion regarding the efficacy of these exercises on respiratory function, including chest mobility, lung capacity, and respiratory muscle strength in FSP.
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 5 days/week for 8 weeks. The distance from the acromion process to the wall was measured as 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) were assessed at the pre- and post-exercise intervention.
Results: After the 8 weeks training program, an improvement in FSP was observed 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 when compared to those in the control group. The strength generated in respiration also improved in the exercise group (MIP, $p < 0.013$).
Conclusions: The 8-week pectoral muscle stretching and scapular stabilizer strengthening could reduce the FSP, improving chest mobility and respiratory muscle strength.

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

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Introduction

The habitual poor posture in everyday tasks might cause upper body muscular imbalance, which is a potential risk of various shoulder problems and respiratory functions [1,2]. Forward shoulder posture (FSP) is a postural misalignment resulting from the agonist and antagonist muscular imbalance, 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]. The imbalance of 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, associated with dyspnea and respiratory dysfunction, the FSP progressively conforms to a slump position characterized by an increase in a forward head posture and thoracic kyphosis (TK) angle [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 deteriorates the respiratory system. The group of the anterior shoulder girdle muscle tightness, 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 demonstrated the correlation between elevated FSP and diminished pulmonary capacity, i.e., vital capacity, forced vital capacity (FVC), and expiratory residual volume [18]. It was evident that the treatment for alleviating FSP was an essential component of the rehabilitation program to prevent shoulder injuries and improve respiratory efficiency [18,19]. One suggestion, stretching tight muscles and strengthening weak muscles would be effective for correcting muscular imbalance [12]. Interestingly, many studies have also 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 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 the university. Sample size determination was calculated using the G-power program in version 3.1.9.2 (University of Kiel, Kiel, Germany) [23]. ANOVA with repeated measures and interaction within-between factors was used to calculate a statistical power of 0.8, an α error probability of 0.05, and an effect size of 0.68. The sample size from the calculation was 12 participants per group. However, assuming that 10% would drop out equally, two additional participants were added per group. Therefore, the present study was conducted in two groups with 14 participants each. Twenty-eight female participants with an average age of 20.00 ± 1.40 years and body mass index (BMI) of 20.10 ±1.60 kg/m^2 were enrolled in the study. 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 were females with FSP, healthy BMI (18.50-24.90 kg/m2), and no underlying diseases [24,25]. A 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 were 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 denial of participation [4,26,27].

Randomization and blinding

After the assessment of the baseline characterization, the participants were assigned to the study groups and randomized allocation sequence by computation. The exercise group participated in the training program for 8 weeks, as followed by the previous studies [28–30]. Simultaneously, the control group received no exercise training and was educated on FSP management, i.e., postural awareness. The outcomes of the baseline and week 8 (post-exercise) were blinded to the group's allocation. The personnel information received from the statistical analyses was blinded to the interventions, which were identified by a numerical code.

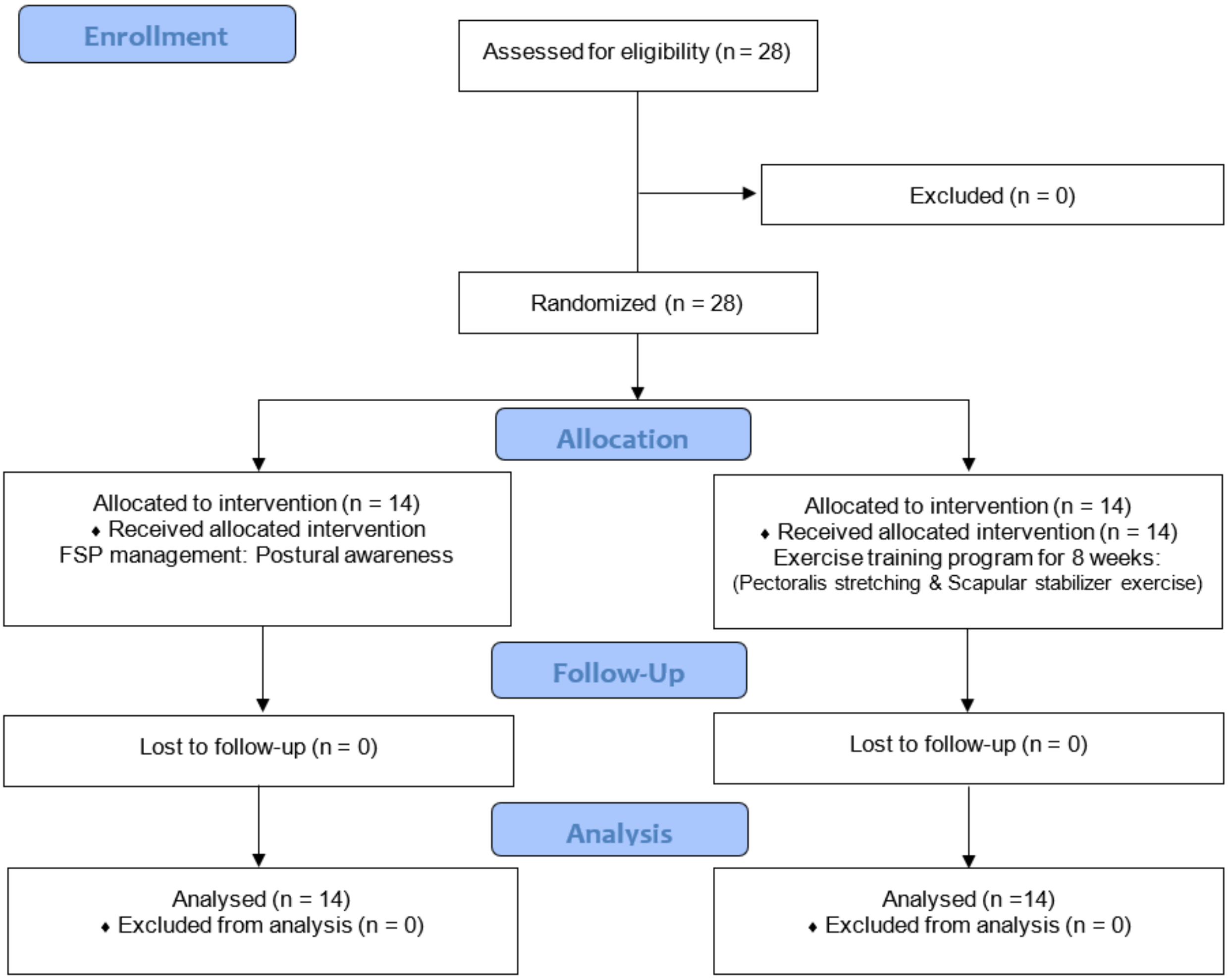

Fig. 1. Diagram CONSORT 2010 flowchart of participation process in the study

Procedure

The procedures to assess main outcomes, including forward shoulder posture, pectoralis minor length, thoracic kyphosis, chest expansion, maximum pressure generated in respiration, and forced vital capacity, were based upon a previous report from our current study [31].

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 measurement of the distance from the wall to the anterior aspect of the subject's acromion process indicated the magnitude of FSP in millimeters. The base of the vernier height gauge was located on the wall; consequently, the instrument's tip was moved and placed on a marker at the anterior tip of the acromion process. The assessment of the FSP was performed side by side 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 by 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 taken from the difference in the thoracic wall dimension during 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. The fifth thoracic spinous process (T5) and the third intercostal space at the mid-clavicular line were marked on the upper chest area. The seventh thoracic spinous process (T7) and the fifth intercostal space at the mid-clavicular line were marked for the middle chest area. 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 in centimeter water pressure (cmH_2O). The evaluation was conducted in accordance with the criterias 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 subjected to the sitting position with a nose clip. MIP was recorded during the maximal inspired maneuver from the residual volume, whereas MEP was noted during the Valsalva maneuver of the maximal expiration from the total lung capacity. The measurement was performed at least for 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 liters 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 began pectoral muscle self-stretching followed by strengthening of the lower trapezius and serratus anterior muscles 5 days a week for 8 weeks [20].

Pectoralis stretching exercise

During the stretching exercise, 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, 10 seconds for holding, and a 30-second break in 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 6 weeks, then the difficulty was increased with an extended elbow for the last 2 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 for strengthening of the serratus anterior [41]. A chair of standardized height of was used in all sessions. From weeks 1-6, push-ups on the wall were set, whereas the standard push-ups plus on a stability chair support with the feet on the floor were done from week 7 to week 8. The participant was instructed to maintain that posture while performing the push-up position. The subject moved the shoulders forward to promote scapular protract and then backward to perform the 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 International Business Machines (IBM) SPSS program in version 23 (IBM Corp., USA). The Shapiro-Wilk test was used to determine the normal distribution and parametric test was used for analyses. The characteristics of the participants at the baseline are expressed as the 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 showed the ICC between 0.92 and 0.99, which were considered as having 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.

Tab. 1. Baseline characteristics of all participants

	Control Group	**Exercise Group**	
	Means ± SD	Means ± SD	***p*-value**
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_2− centimeter of water, kg− kilogram, kg/m^2− kilogram per square meter, MEP− maximum expiratory pressure, MIP− maximum inspiratory pressure, mL− milliliter

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 difference of the 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 the controls (Fig. 2A-B). Moreover, the mean difference of the PL in the exercise group was higher than the controls (left side, p = 0.014; right side, p = 0.008) (Fig. 2C). These results suggested that the 8 weeks exercise training program combining pectoral muscles stretching and scapular stabilizer strengthening could alleviate the FSP and the degree of TK, which was accompanied with an increase in PL.

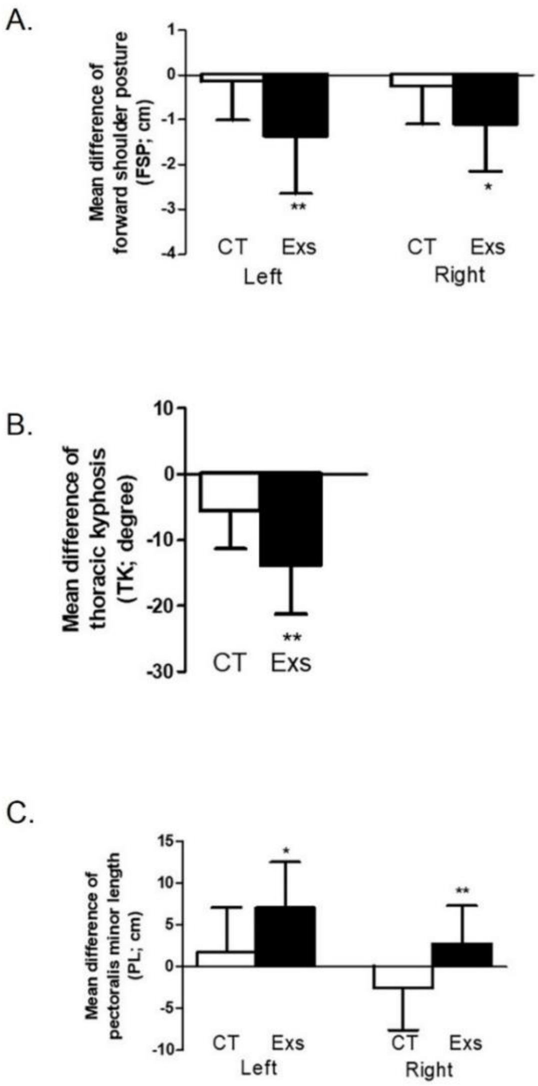

Fig. 2. Changes in forward shoulder posture. (A) Mean difference of forward shoulder posture (FSP; cm), (B) Thoracic kyphosis (TK; degree), and (C) Pectoralis minor muscle length (PL; mm) after the 8 weeks of exercise training in control (CT) and exercise group (Exs).*p <0.05 , **p <0.01 compared to control group

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

In terms of the three parts of the chest expansion (Fig. 3A-C), the exercise-trained group showed an improvement in the mean difference for the expansion of chest as compared to control group. Therefore, the 8 weeks of reducing FSP exercise program alleviated lower part of the chest restriction ($p = 0.010$) (Fig. 3C) but no changes in the upper ($p = 0.813$) (Fig. 3A) and middle ($p = 0.912$) (Fig. 3B) parts of the chest expansion.

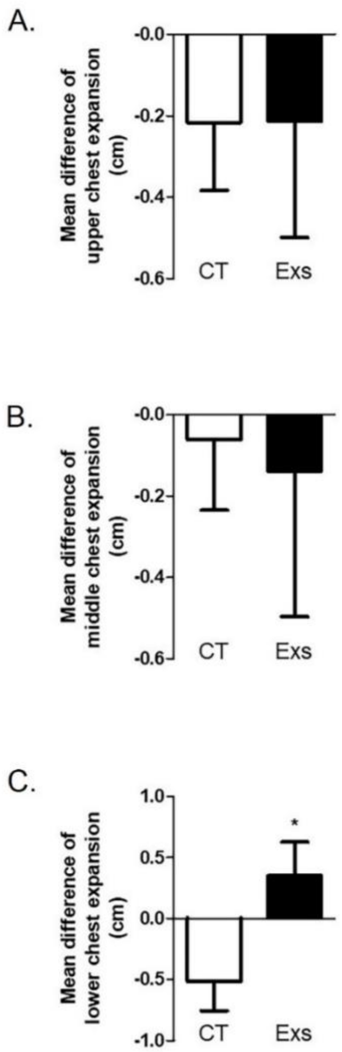

Fig. 3. Changes in chest expansion. (A) Mean difference of upper chest , (B) middle chest, and (C) lower chest expansion in control (CT) and exercise group (Exs) after the 8 weeks of exercise training for reducing forward shoulder posture. *$p < 0.05$ compared to control group

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

The change in the inspiratory muscle strength of the exercise group, measured by MIP (Fig. 4A), significantly increased between groups ($p = 0.013$). The mean difference of MIP in the control group was 3.71 ± 2.84 cmH_2O and in the exercise-trained group was 15.29 ± 3.27 cmH_2O, whereas the expiratory muscle strength as measured by MEP (Fig. 4B) revealed no significant difference ($p = 0.433$). Therefore, this indicated that the FSP improvement as a result of the 8 weeks exercise training program could create the maximum force during inspiration. Regarding the FVC (Fig. 4C), the exercise-trained group showed a gradual increase when compared to the control, but this did not reach a statistical significance (p = 0.072), thus pointing out the tendency for lung capacity improvement through the 8-weeks exercise for the reduction of FSP.

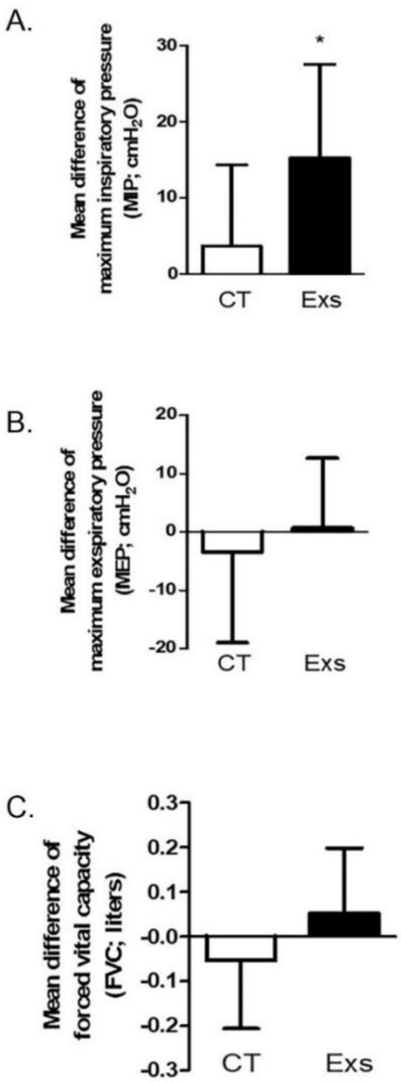

Fig. 4. Changes in maximum inspiratory pressure. (A) Mean difference of Maximum inspiratory pressure (MIP; cmH_2O), (B) Maximum expiratory pressure (MEP; cmH_2O), and (C) Forced vital capacity (FVC; liter) in control (CT) and exercise group (Exs) after the 8 weeks of exercise training for reducing forward shoulder posture *$p < 0.05$ compared to control group

Discussion

Muscular imbalance resulting from poor posture contributes the most to postural misalignments, including FSP, and develops musculoskeletal and respiratory problems

[1,2,43]. The pectoral muscle tightness and scapular stabilizer weakness, particularly the lower trapezius and serratus anterior, were major characteristics of upper quadrant muscular dysfunction in FSP [3,4,9]. These imbalances subsequently lead to the abnormal plane of the scapular movements, including anterior tipping, internal rotation, and downward rotation [9,17,39]. The findings of this study revealed that the exercise program, comprising pectoral muscles stretching and scapular stabilizer muscles strengthening, for 5 days/week for 8 weeks could reduce FSP that was increased in PL and decreased in TK. In addition, the reduction of FSP led to an improvement in inspiratory muscle strength and chest expansion.

Presently, the exercise interventions of this study were selected due to their quality of stretching the tightened muscles and strengthening the weak muscles in the FSP [2,3]. Furthermore, the results were consistent with previous findings of reduced FSP with muscular imbalance correction undertaken by stretching and strengthening exercises. Similarly, the 6-week combined manual treatment and stabilizing exercises could improve function and posture in female with forward head and rounded shoulder postures [44]. As compared to conventional physiotherapy treatment, 6-week scapular stabilization exercise was a part to promote postural adjustment and relive the pain for female patients with neck pain [45]. Regarding the effects of the pectoral muscle stretching program, the 2-week pectoral muscle stretching program improved the scapular position and decreased FSP [3]. Moreover, the 6-week anterior shoulder stretching and posterior shoulder strengthening exercises could reduce FSP in competitive swimmers [32]. Furthermore, the unilateral corner self-stretch of the pectoral muscles at 90^{o} shoulder abduction produced the greatest length change in the pectoralis minor muscle and maximally reduced FSP [9]. Hence, it would be likely that the 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 the muscle spindle activity. Hence, reduced tension in the pectoral muscles would further relax them to increase their lengths and reduce FSP [15].

In order to alleviate the muscular imbalance in FSP, the strength of agonist muscles (scapular stabilizers), particularly the lower trapezius and serratus anterior, was used actively to counteract the weakness and movement loss associated with FSP [46]. When the agonist muscles contracted, the tension in the antagonist muscle (pectorals) was inhibited by impulse signals from the motor neurons, and thus they are simultaneously relaxed [15, 46]. The strength of agonist muscle groups enhanced scapular retraction, an upward rotation, posterior tilting, and thus restoring the scapular plane in FSP [47]. Additionally, the 6-week pectoral muscle stretching and scapular retractor and elevator strengthening exercises promote scapular stability

[48]. Furthermore, the scapular stabilization exercise after pectoralis muscle stretching could decrease FSP and increase the pectoralis minor index [28]. In addition, this combined intervention was the most effective treatment for improving lower trapezius muscle activity, as shown by the electromyography (EMG) data [22]. Therefore, these studies clearly supported the exercise training program's effectiveness in reducing FSP. Further studies with EMG measurements to confirm the muscular activities would be beneficial.

The present study was the first to be conducted with the aim of assessing the effects of stretching and strengthening exercise respiratory functions of subjects with FSP. The solution was correcting the muscular imbalance and improving posture by reducing the degree of TK in participants with FSP. This finding concurred with previous study regarding the prevalence of TK accompanying FSP in individuals [41]. In FSP, the narrowing of the subacromial space caused by the shoulder muscle imbalance was induced in the presence of thoracic hyperkyphosis and was also associated between the degree of TK and scapular protraction [49]. The TK associated with dyspnea and respiratory dysfunction was observed in older people [13,50]. Additionally, a slumped sitting posture resulted in position shifting of the ribs and the pelvis, which increased intra-abdominal tension and made it difficult for the diaphragm to descend caudally [10]. Moreover, the approximation could render the intercostal muscles in non-optimal lengths and make 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 the 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 this 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]. Nevertheless, the exercise for reducing the FSP in this study might be unrelated to abdominal muscle recruitment. In considering the lung capacity, the combination of therapeutic exercises, including scapular stabilization and thoracic mobility, improved forced expiratory volume at 1 second but not FVC [53]. Similarly, our results could not show a significant difference in FVC after the prescription of reducing the FSP exercise program. However, it tended to delay a reduction of age-related FVC [54]. Despite this limitation, healthy female subjects were recruited for this study; therefore, male subjects might be different and still need further investigation.

Conclusions

The 8 weeks pectoral muscle stretching and scapular stabilizer strengthening exercises could alleviate FSP leading to improve TK, chest expansion and inspiratory muscle strength in sedentary participants. As aforementioned, these exercise interventions were the least cost-effective procedure and could be applied to prevent and alleviate poor posture and muscular imbalance in a healthy population and/or in individuals with pulmonary diseases. Additionally, the benefits of our exercise regimen will be applied to patients presented with mild to moderate chronic obstructive pulmonary disease in further study.

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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, Jaysrichai T , Lapmanee S. The functional correction of forward shoulder posture with kinesiotape improves chest mobility and inspiratory muscle strength: A randomized controlled trial. Ann Appl Sport Sci. e-ISSN: 2322–4479; p-ISSN: 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 measurement 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.