

Correlation between thoracic kyphosis and pulmonary function in elderly

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ABSTRACT

Background: Thoracic kyphosis is almost found in the elderly and reduces chest expansion which results in decreasing pulmonary function including lung function and respiratory muscle strength, then, it leads to dyspnea and exercises intolerance in the elderly.

Objectives: To evaluate thoracic kyphosis measured by flexicurve method in relation to pulmonary function in elderly.

Materials and methods: Sixty-six participants aged 65 years and older were recruited for the study. All participants received basic health screening and underwent thoracic kyphosis measurements using flexicurve method. All subjects went through the lung function tests by using spirometer and respiratory muscle strength measurements by using maximal voluntary respiratory pressures. Pearson's correlation coefficient was used to analyze the relationships between variables.

Results: Thoracic kyphosis was mild positive correlated with lung functions in Forced Vital Capacity (FVC), Forced Expiratory Volume in 1 second (FEV₁) and Vital Capacity (VC) parameter ($r=0.265$, 0.303 and 0.322 , respectively, $p<0.05$) but not with FEV₁/FVC ratio (%) ($p>0.05$). There was no correlation between thoracic kyphosis and respiratory muscle strength (maximal inspiratory pressure (MIP) and maximal expiratory pressure (MEP)) ($p>0.05$).

Conclusion: Thoracic kyphosis measured by the flexicurve method had a mild positive correlation with the lung functions.

Introduction

Elderly population is taking place throughout the world.¹ The proportion of the elderly population in Thailand aged 65 years and older has been increasing with the rising estimation from 6.8% in 1994 and 16.7% of the population in 2017.² Therefore, rapidly change in the proportion of a population that is elderly result in healthcare professional awareness and preparation to deal with elderly changes in physical and mental functions, as for a good quality of life.¹ Physiological changes occur with elderly in all organ systems

contribute to functional limitation that can predict mortality.³ Changes in the respiratory system include internal and external structures such as thoracic wall, spine, and respiratory muscles lead to breathing control problem. Besides, musculoskeletal system changes in elderly for instance collapse wedging of vertebrae resultant in thoracic kyphosis with rib cage deteriorated. These changes in musculoskeletal system reflect on breathing control problem thus lead to respiratory infection⁴ and increase vertebral and extremity fracture.^{5,6} Skloot et al.⁷ suggested lung function testing is benefit for the elderly because it is a noninvasive technique used for severity assessment and prognosis in lung disease including restrictive, obstructive, or mixed abnormalities. Spirometry is the most popular in lung function testing because it is easy, quick, benefit, and high reliability.⁸

Shin et al.⁹ reported that respiratory muscle strength including MIP and MEP variables related to SMI (skeletal

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muscle mass index) in the elderly. This study expects that inspiratory and expiratory muscle strength may be related to thoracic kyphosis, which respiratory muscle strength are determined by using the maximal voluntary respiratory pressures. It is low cost, portable equipment, easy and rapid to perform, noninvasive as well. The maximal voluntary respiratory pressures has been proved to be a measurement determining the MIP and MEP.^{10, 11}

Thoracic kyphosis affects 20-40% of elderly and can be considered as a kyphosis angle which is exaggerated anterior curvature of the thoracic spine more than 40 degrees.^{5, 6, 12, 13} Furthermore, female tends to be more thoracic kyphosis than male, due to losses of estrogen in menopausal and postmenopausal period.⁶ In addition, age is also an important factor that relate to thoracic kyphosis. The kyphosis angle varies in between 20 to 29 degrees in aged under 40 years, 53 degrees in aged between 60-74 years and 66 degrees in aged above 75 years of age.⁵ As a result, thoracic kyphosis can cause restrictive and obstructive ventilation. The biomechanics of kyphosis which increases the external moment, inducing trunk curvature and chest compression lead to limitations in rib cage expansion resulting in a restricted amount of oxygen taken in inspiration and expiration, additional leading to dyspnea and exercise intolerance; and consequently, causing a decrease in activity of daily living and an increase in mortality.^{5, 6} Cobb angle measurement of spine from X-Ray images is a gold standard to measure thoracic kyphosis, however, it has disadvantages including cost, time-spent to interpret, and a requirement of specialist and invasive technique to measure.¹⁴ In contrast, the non-invasive technique which is similar to gold standard ($r=0.98$)¹⁵ is flexicurve method. It has a number of advantages including with low cost, easy to get, quickly to interpret, high validity and reliability ($ICC>0.9$).¹⁶ Few studies have investigated the association between thoracic kyphosis and pulmonary function in elderly,¹⁷⁻¹⁹ however, there are confounding factors which have an effect on research result such as history of smoking and gender. Lorbergs et al.¹⁷ reported that elderly woman with thoracic kyphosis tended to decrease pulmonary function more than those with erect posture. It was found that FEV₁ decreased by 100 ml or 6.3 ml/years. However, results of research that has developed control confounding factor consist of unaware of history of smoking which is quit smoking at least 1 year might result in lung recovery fully²⁰ and thoracic kyphosis measurements used in previous study were invasive technique which is hard to measure in community.^{17, 18} Moreover, at present there is no evidence measuring thoracic kyphosis and correlation with pulmonary function in elderly.

This study aimed to evaluate thoracic kyphosis measured by flexicurve method in relation to pulmonary function in elderly.

Materials and methods

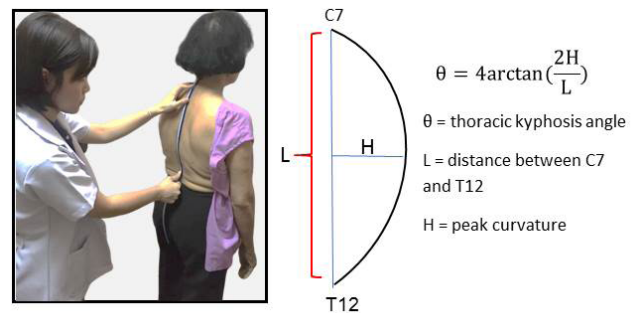


Figure 1. Thoracic kyphosis measurement by using flexicurve method and calculated by using the equation of thoracic kyphosis angle.

Participants

This study included 66 elderly, aged 65 years and older, living in Chiang Mai, Thailand. Flow chart of sources of study participants shows in Figure 2. All subjects underwent thoracic kyphosis measurements using flexicurve method and cognitive impairment measurements using the Montreal Cognitive Assessment-Thai version (MoCA-Thai). They were all non-smoker or quit smoking for 1 year and longer,²⁰ who walked with or without walking aids, understand command and consent to participate in the research, had thoracic kyphosis angle more than 40 degrees^{5, 6, 12, 13} with no cognitive impairment (MoCA score ≥ 23 points).²¹ Subjects who had contraindications for spirometry measurements such as hemoptysis,^{8, 22, 23} contraindications for respiratory muscle strength measurements such as aneurysm in thoracic, abdominal or brain,²⁴ had musculoskeletal complications involving thoracic kyphosis measurements such as leg length discrepancy (more than 3 cm)²⁵ or leg deformity which involve standing or pain on musculoskeletal system more than 5 points (visual analog scale 0-10) or severe scoliosis,²⁶ had neurological disorder which involve measurements such as cerebrovascular accident (CVA) or Parkinson's disease, had uncontrolled underlying disease such as hypertension, heart disease or asthma, had diagnosed spinal fracture by physician and take medication which involve measurements such as opioid or antidepressant²⁷ were excluded from the study. G-Power version 3.1 estimated a required sample size of 66 participants (effect size=0.32, $\alpha=0.05$, and power=0.8).¹⁸

Thoracic Kyphosis

Thoracic kyphosis was measured using flexicurve method. The subject was instructed to be in standing position with comfortable and felt natural. A single trained reader used flexicurve ruler. The superior end of the ruler was placed at C7 and the inferior end of the ruler at T12. The ruler was then placed flat on 10x10 grid paper and then ruler position drawn from C7 to T12. The flexicurve was printed to the spine 3 times, being flattened between each measurement. The thoracic kyphosis angle was later calculated using the formula¹² displayed in Figure 1. The average of the 3 measurements of each subject was used for analysis.²⁸ If the calculated angle was greater than 40 degrees, the participant was considered to be thoracic kyphosis and included in this research. The intra-class

correlation coefficient (ICC) estimating as 0.984 (95% confidence interval: 0.939-0.996) for 10 participants,

chosen at random and measured in duplicate.

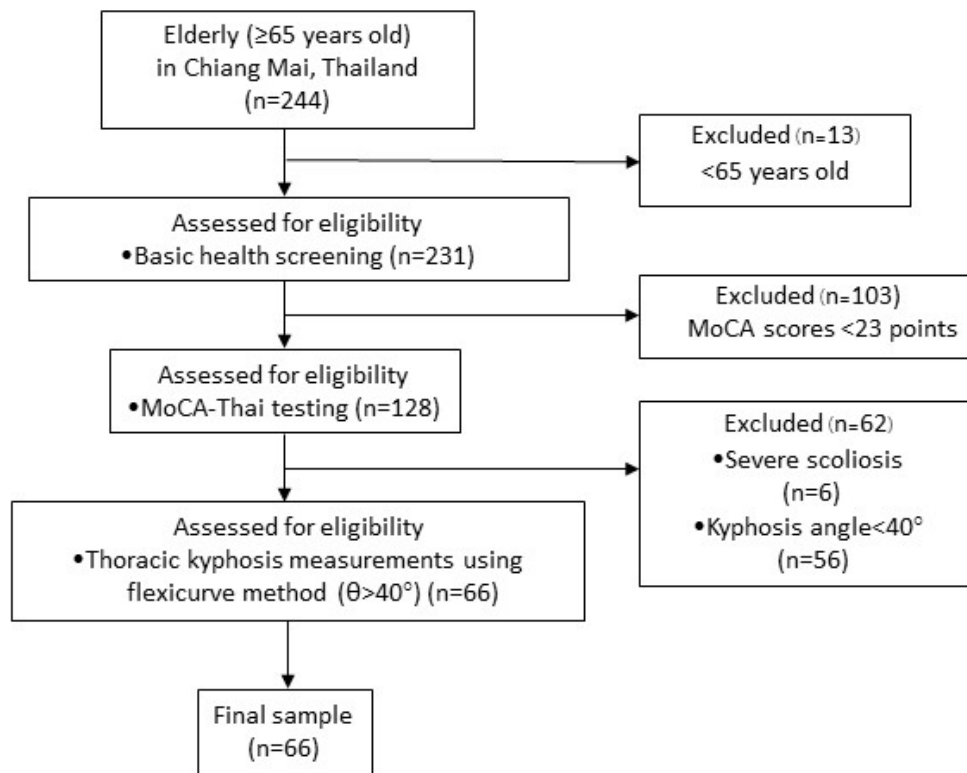


Figure 2. A flow chart of the participants in the study.

Lung function tests

Lung functions including forced vital capacity (FVC), forced expired volume in one second (FEV_1), FEV_1 /FVC ratio and vital capacity (VC) were measured by CHESTGRAPH HI-105 spirometer (Chest MI, Inc, Tokyo, Japan) according to the American Thoracic Society (ATS) criteria.²⁹ Measurements were made using a closed-circuit spirometer with the subjects seated, feet resting on the floor, spine erect and wearing a nose clip. Subjects were asked to perform a maximum of five forced expiratory maneuvers for measuring FVC, FEV_1 and FEV_1 /FVC ratio and were asked to perform a maximum of slow expiratory maneuvers to measuring VC to obtain three acceptable spirogram. Dejsomritrutai equations were used to determine the normal values based on age, sex, height and race.^{8, 22, 23}

Respiratory muscle strength

Respiratory muscle strength was assessed by using the MicroRPM portable manometer's measurements of maximum inspiratory pressure (MIP) and maximum expiratory pressure (MEP)³⁰ (MicroRPM, Carefusion, Kent, and United Kingdom). Subjects were seated, feet resting on the floor, spine erect, wearing a nose clip and then, who were asked to perform a maximal expiratory effort after taking a maximal inspiration to measure a maximal expiratory pressure (MEP) and were instructed to ensure maximal inspiratory effort after exhaling a maximal expiration to measure maximal

inspiratory pressure (MIP). Each participant was allowed to hold in 1.5 seconds per time, rest for about one minute and then repeat the maneuver 3 times. The highest value for MIP and MEP were chosen.^{10, 11}

The thoracic kyphosis, lung function, and respiratory muscle strength measurements were examined by individual examiners. Besides, lung function and respiratory muscle strength measurements examiners were blinded to clinical status and kyphosis angle variables.

Statistical analysis

Descriptive analyses were presented as a mean±standard deviation, according to the results of the Kolmogorov-Smirnov test which was used to test the assumption of normality. The kyphosis angle, lung function and respiratory muscle strength data were normally distribution, thus all parameters were analyzed by using Pearson's correlation coefficient. The Correlation coefficient values were interpreted as follows: 0.00-0.10 negligible, 0.10-0.39 mild, 0.40-0.69 moderate, 0.70-0.89 strong and 0.90-1.00 very strong. The level of statistical significance was considered as $p < 0.05$.³¹

Results

Participant's demographics

Demographic characteristic of participants is shown in Table 1. Among the 66 elderly participants, 15 (22.7%) of them were males and 51 (77.3%) were females. The mean age was 71.09 ± 5.55 years. The mean BMI was 24.66 ± 3.61 kg/m², and the mean kyphosis angle was 50.14 ± 9.19 degrees. All

participants had no history of smoking, did not work, and had underlying disease with medical supervision including hypertension, dyslipidemia, diabetes mellitus type 2, gout, and knee osteoarthritis. The percentage of participants in the three ranges of kyphosis angle were 57.58% for the 40-50 degrees, 33.33% for the 50-60 degrees, and 9.09% for the 60-100 degrees.

Table 1 Demographic characteristic of participants (n=66).

Variables	Min-Max	Mean $\pm$ SD
Gender, (n%)		77.30
Male (n)		15 (22.7%)
Female (n)		51 (77.3%)
Age (years)	68-86	71.09 $\pm$ 5.55
Height (cm)	143-172	153.83 $\pm$ 5.60
Weight (kg)	39-75	57.62 $\pm$ 7.87
BMI (kg/m ²)	17.3-35.7	24.66 $\pm$ 3.61
Kyphosis angle (°)	40.15-93.04	50.14 $\pm$ 9.19
MoCA (score)	23-30	25.86 $\pm$ 2.25

Abbreviation: BMI, body mass index.

Correlations between the thoracic kyphosis angle and lung function

The correlation results are provided in Table 2 and Figure 3. There were mild positive correlations between the

thoracic kyphosis angle and FVC, FEV₁ and VC ($r=0.265$, 0.303 and 0.322 , respectively, $p<0.05$) (Figure 3A, 3B and 3D). There was no correlation between thoracic kyphosis angle and FEV₁/FVC ratio (%) ($p>0.05$).

Table 2 Correlations between the thoracic kyphosis angle and lung function (FVC, FEV₁, FEV₁/FVC ratio and VC).

Variables	Min-Max	Mean $\pm$ SD	r	95% CI	p value
FVC (L)	0.43-3.28	1.72 $\pm$ 0.58	0.265	0.009-0.434	0.032*
FEV ₁ (L)	0.33-3.26	1.45 $\pm$ 0.49	0.303	0.110-0.458	0.013*
FEV ₁ /FVC ratio (%)	64.56-100.00	85.08 $\pm$ 9.03	0.100	-0.116-0.321	0.425
VC (L)	0.66-3.28	1.66 $\pm$ 0.55	0.322	0.067-0.523	0.008*

Data were analyzed using Pearson's correlation, FVC: Forced vital capacity, FEV₁: forced expiratory volume in one second, VC: Vital capacity, * $p<0.05$ showed significance.

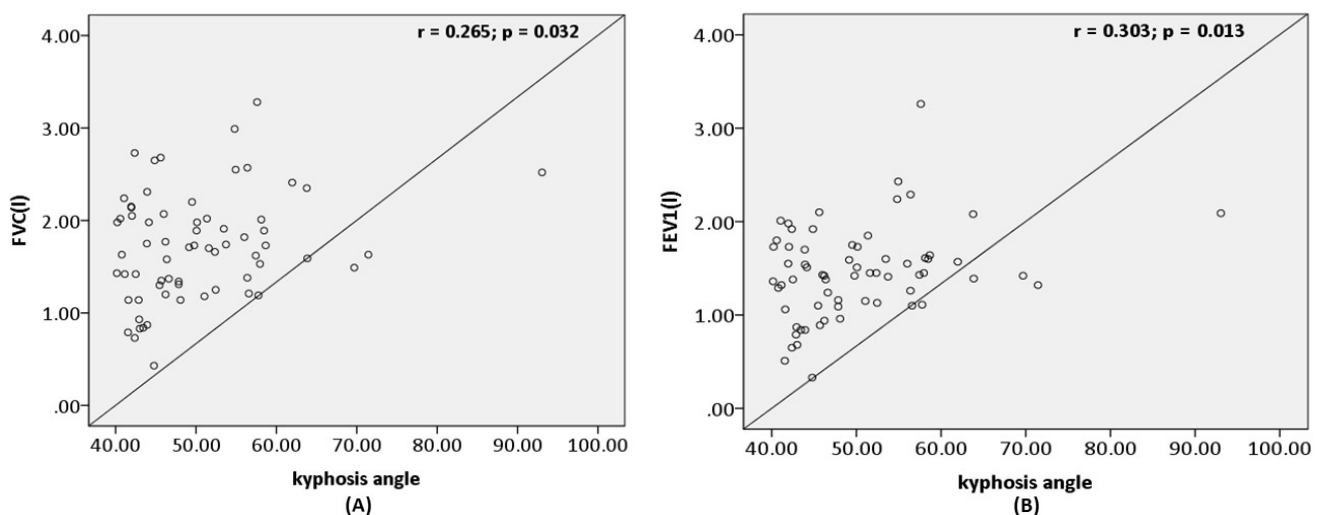


Figure 3. The correlations between the thoracic kyphosis angle and lung function. A) FVC B) FEV₁ C) FEV₁/FVC ratio D) VC.

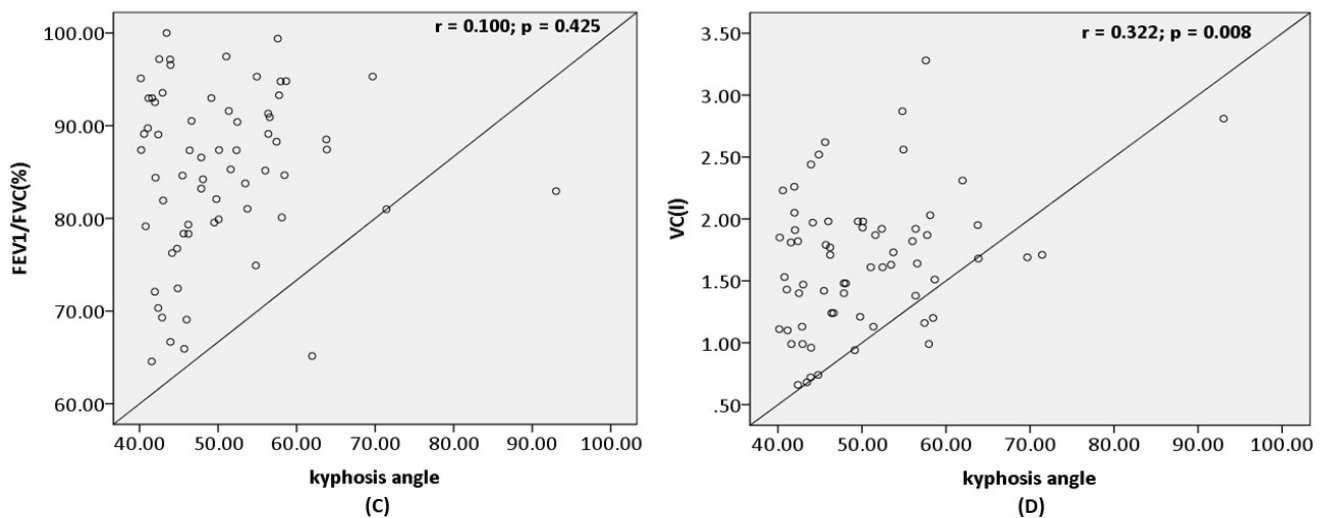


Figure 3. The correlations between the thoracic kyphosis angle and lung function. A) FVC B) FEV₁ C) FEV₁/FVC ratio D) VC.

Correlations between the thoracic kyphosis angle and respiratory muscle strength

There were no correlation between thoracic kyphosis

angle and MIP and MEP ($p > 0.05$). The correlation results are provided in Table 3 and Figure 4A and 4B.

Table 3 Correlations between the thoracic kyphosis angle and respiratory muscle strength (MIP and MEP).

Variables	Min-Max	Mean $\pm$ SD	r	95% CI	p value
MIP (cmH ₂ O)	19-123	61.61 $\pm$ 24.37	-0.081	-0.315-0.126	0.518
MEP (cmH ₂ O)	36-175	78.91 $\pm$ 26.90	-0.167	-0.362-0.041	0.179

Data were analyzed using Pearson's correlation, MIP: Maximal inspiratory pressure, MEP: maximal expiratory pressure. * $p < 0.05$ showed significance.

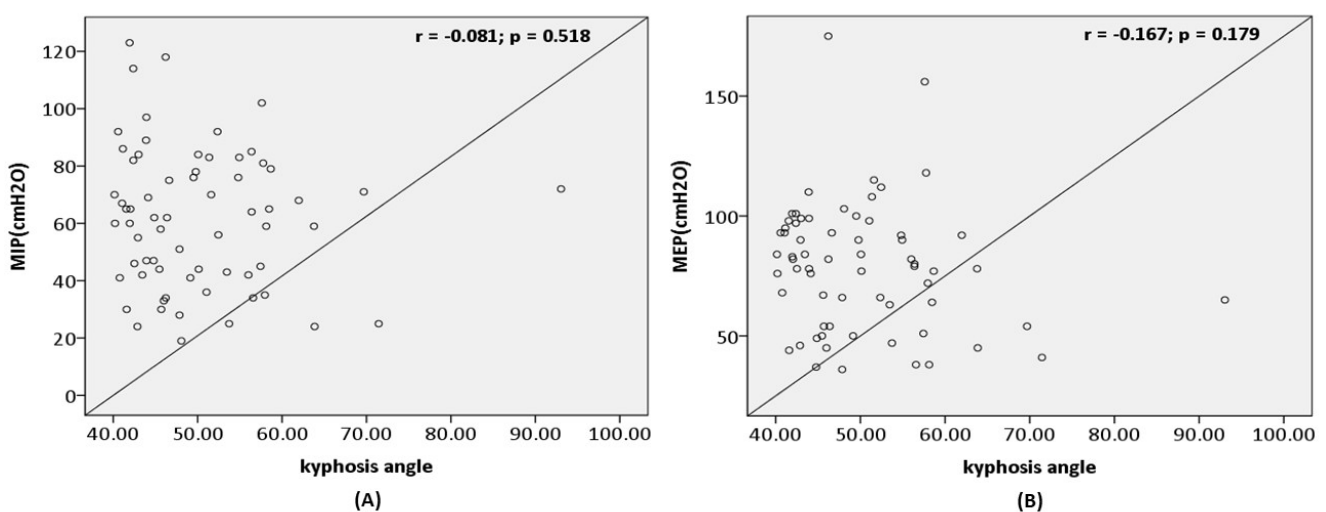


Figure 4. The correlations between the thoracic kyphosis angle and respiratory muscle strength. A) MIP B) MEP.

Discussion

The aim of the present study was to examine the correlation between thoracic kyphosis and pulmonary function in elderly. In the present study, we found that thoracic kyphosis angle was positive correlated significantly with the lung functions (FEV₁, FVC and VC) of elderly. However, thoracic kyphosis angle was not significantly correlated with FEV₁/FVC ratio and respiratory muscle strength (MIP and MEP).

In addition, the percentage of participants in the ventilatory defects was 34.85% for the normal, 59.09% for the restrictive, 1.52% for the obstructive, and 4.55% for the mixed lesion.²² The thoracic kyphosis was mildly positive correlated with the lung functions in VC, FEV₁ and FVC parameters. Our results are consistent with the study of Mellin G et al.,³² determining the relationship between thoracic spinal mobility and kyphosis and lung function. Thoracic kyphosis was measured by using an inclinometer and thoracic spinal mobility was measured by using a goniometer. They found that thoracic spinal mobility was significantly positive correlated with lung function (FEV₁ and VC parameters) ($r=0.16$, $p<0.05$) which may suggest that an increase in chest expansion, thereby an increase in lung volume. However, the results were in disagreement with the findings of previous studies regardless of thoracic kyphosis and pulmonary function.¹⁷⁻¹⁹ Rahman et al.¹⁸ found a significant mild correlation between the thoracic kyphosis measured by using electromagnetic motion tracking system and lung functions (FEV₁ and FVC) in elderly ($r=0.232$ and 0.317 , respectively, $p<0.05$). A cross-sectional study of Bari et al.¹⁹ reported that the worse kyphosis evaluated by using occiput to wall distance and standing stature adjusted for tibia length was associated with reduced FVC and FEV₁. Besides Lorbergs et al.¹⁷, also found similar results in prospective studies and reported that elderly women with thoracic kyphosis measured by radiographic examination tended to have a decrease in pulmonary function (FEV₁) more than those with erect posture. Furthermore, thoracic kyphosis was found to be mildly positive correlated with vital capacity ($r=0.322$, $p<0.05$), which is inconsistent with the findings of a previous study³³ which reported that women with osteoporosis-related kyphosis had significantly lower VC ($p<0.05$). These differences in results between the studies may be related to the methodology used for the analysis of lung functions, the previous study^{17, 19} used bell spirometer which low impact on restrictive ventilatory measurement and may result in overestimated. In addition, participants characteristics in the previous studied were different.¹⁷⁻¹⁹ These included no variety in sources of study participants,^{17, 19} low physical activity and activity daily living,¹⁸ no control in respiratory disorder, history of vertebral fracture¹⁹ and history of smoking^{17, 19} which may cause of low lung functions. Hence, this result was inconsistent with other studies and resulted in thoracic kyphosis was positive correlation with lung functions. Accordingly, the factors which may impact on the positive correlation in thoracic kyphosis angle with lung functions (FEV₁, FVC and VC) in this study were healthy elderly (no respiratory disease and uncontrol in underlying disease), no diversity in the kyphosis

angle because the number of participants considered for measuring the kyphosis angle almost in 40-50 degrees which is the low kyphosis angle result in mildly positive correlated. There was no correlation between thoracic kyphosis and FEV₁/FVC ratio, and also respiratory muscle strength (MIP and MEP). Suggestion participants in this study were healthy who not had a disease in the nervous system or neuromuscular which almost a problem leads to respiratory muscle weakness. This result is in accordance with a previous study,¹⁸ which found that lung functions in FEV₁/FVC ratio parameter, MIP and MEP were not correlated with thoracic curvature. However, MIP and MEP significantly correlated with lumbar curvature, since the diaphragm is the main inspiration structure and it attaches mainly at the lumbar spine.¹⁸ The researchers performed analysis into subgroups of gender (males and females) and kyphosis angles (40-50, 50-60, 60-100 degrees). It was found that both gender and kyphosis angles were not correlated with lung functions ($p>0.05$).

The limitation of the present study was that the participants recruited in the study were women more than men (77.30% and 22.70%, respectively). In addition, this study used medium effect size (effect size=0.32) which lead to small sample size ($n=66$) and had effect on data distribution, in which there was no diversity in the kyphosis angles. Hence, this study has several strengths. The examiners and evaluations were blinded to clinical status and kyphosis angle variables. Besides, it was difficulty to select participants and noticed that 66 participants from 244 participants who passed in screening of inclusion criteria. Almost elderly has memory and cognition problem to assess the spirometry and maximal voluntary respiratory pressures, therefore, this study was used MoCA-Thai testing to assesse memory and cognition which is easy to collect data and good reliability tool. Additionally, these findings had represented diversity of participants including community-dwelling older adults living in rural areas, older adults living in residential institutions and citizen club at a suburban area. However, this study did not assess parameters on chest expansion, thoracic spinal mobility, flexibility, and physical activity which may impact on lung functions. Further study is needed to focus on these parameters. Especially, physical activity may be measured by using questionnaires such as the Community Healthy Activities Model Program for Seniors (CHAMPS), Physical Activity Scale for the Elderly (PASE) or Modified Baecke Physical Activity questionnaire.

Conclusion

We found that thoracic kyphosis was mildly positive correlation with lung functions in elderly, but FEV₁/FVC ratio parameter, MIP and MEP were not correlated with thoracic kyphosis. Thoracic kyphosis measurements using the flexicurve method may provide a trend to predict lung function associated with thoracic kyphosis. Further study is warranty.

Conflicts of interests

There were no conflicts of interest.

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Ethical approval

Approved number AMSEC-62EX-041.

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