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Lower thoracic spine extension mobility is associated with higher intensity of thoracic spine pain

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ABSTRACT

Objectives: To evaluate the association of thoracic spine (TS) posture and mobility with TS pain.

Methods: Participants with TS pain reported maximum, average, and night pain in TS area, and pain summary score was calculated. Upright and sitting TS postures were evaluated by inspection. TS posture and mobility (flexion and extension) were recorded using an inclinometer and a tape measure, respectively. Correlations between posture and mobility assessments were calculated using Spearman rank correlation, the association of TS posture and mobility with TS pain by logistic regression analysis.

Results: The participants' (n = 73, 52 females, age range 22–56) TS pain duration was 12 weeks on average. The correlations for measurements of TS posture and flexion mobility were higher than correlations of other TS measurements being between 0.53 and 0.82. Decreased extension mobility of the upper (from 1st to 6th TS segments; Th1–Th6) TS was associated with higher worst pain (OR 1.04, 95% CI 1.00–1.07) and whole TS with pain sum score (OR 1.05, 95% CI 1.01–1.08). Less kyphotic whole TS was associated with lower pain sum score (OR 0.96, 95% CI 0.92–1.00). Greater flexion mobility of upper and lower (Th6–Th12) TS were associated with lower pain sum score (OR 0.96, 95% CI 0.91–1.00, and OR 0.96, 95% CI 0.91–1.00, respectively).

Conclusions: Reduced thoracic extension mobility was associated with higher pain scores and the greater flexion mobility with lower pain scores. Future research is warranted to evaluate if treatments geared toward TS extension mobility improvements would result in lower TS pain.

Introduction

Thoracic spine (TS) has been studied less frequently than the lumbar or cervical spine, possibly because the thoracic region is believed to be less commonly involved, and generate less severe clinical symptoms [1,2]. TS pain can be defined as pain in the TS region in the posterior side of the trunk from 1st to 12th TS segments (Th1-Th12)[3]. Regardless of the rather sparse scientific interest of TS, the prevalence of TS pain is quite frequent, with lifetime prevalence from 12% to 31%[3] and one-year prevalence from 3% to 55% among adult workers, depending on the occupational group investigated[4]. Pain in TS can be caused by numerous factors, from spinal to visceral and systemic structures and conditions[3]. Even though the risk factors for TS pain are not well understood, there are some factors associated with TS pain, such as postural factors [5,6] and trunk bending and driving vehicles among adult workers [3,7].

The kyphotic curvature is a normal expression of the TS, with usually higher than 40 degrees being considered as excessive kyphosis, also called as hyperkyphosis[8]. Kyphosis has been found to increase with age [9,10]. Other causes for hyperkyphosis are congenital abnormalities, osteochondritis of the vertebrae in adolescents [11–13], or simply, a faulty, slumped habitual posture[1]. Among the elderly, hyperkyphosis can be the result of disc degeneration, vertebral fractures, osteopenia, or osteoporosis, especially in women [8,14,15].

The thorax, consisting of ribs, ribcage cartilage, sternum, and the TS, is the stiffest part of the spine, although a certain extent of mobility is also needed [16,17]. Stability and mobility usually act contrary to each other – when stability increases, mobility decreases[17]. The interaction between spinal mobility and posture has been demonstrated; hyperkyphosis is associated with a decreased spinal mobility [18,19]. Increase of thoracic kyphosis also causes higher trunk loading[20].

Thoracic kyphosis is associated with limited daily functioning and upper and middle back pain, while limited thoracic mobility is associated with low back pain especially among older individuals or

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postmenopausal women [13,20–23]. Studies evaluating participants with TS posture are rather rare. Existing studies have generally included asymptomatic postmenopausal women, older adults, or athletes [21–23]. Furthermore, the focus is usually on excessive thoracic kyphosis, whereas decreased kyphosis or a flat TS as a poor posture is often overlooked [21,22].

Pain in the TS has been studied rather infrequently. In addition, regarding risk factors for and factors affecting TS pain, the association of mobility and posture of TS with TS pain is not well understood. Clinically, hands-on examination is one key feature when examining and treating the patient. Therefore, it is of great interest to evaluate the associations of TS mobility and posture with TS pain. The purpose of this study was to examine participants with TS pain and investigate the association of mobility and posture of TS with thoracic pain. We also aimed to evaluate the correlation of different clinical assessment methods. The primary hypotheses were that (1) increased thoracic kyphosis and reduced mobility are at least moderately associated with TS pain, and (2) visual inspection of the TS posture by physical therapist correlates strongly with results obtained by inclinometer.

Methods

This was a cross-sectional study on participants with TS pain primarily recruited from the city of Oulu, Finland. Participants were recruited from primary health-care centers and via newspaper advertisements between 2008 and 2011. Written and informed consent was obtained from every participant, and the study was reviewed by the Oulu University Hospital Ethics Committee. This study was part of the larger prospective TS treatment study (Clinical Trials, NCT01884818).

The participants filled out a questionnaire prior to enrollment. Inclusion criteria were as follows: age between 18 and 55 years; TS pain lasting ≤4 months or substantial increase (Visual Analog Scale [VAS] increase by 30 mm) in the intensity of chronic pain; and a mean of three TS pain intensities (self-reported maximum pain, average pain, and night pain) of at least 35 mm on VAS. This threshold was determined based on the minimal detectable change (MDC) of the VAS in lumbar spine pain as no studies on TS pain MDC have been published[24]. Exclusion criteria were the following: very mild pain (either mean pain, maximum pain, or night pain ≤25 mm) during the last week; fibromyalgia; daily cervical or lumbar spine pain; clinically significant osteophytes or diffuse idiopathic skeletal hyperostosis (DISH); inflammatory diseases such as rheumatoid arthritis or polymyalgia rheumatica; TS instability; malignant conditions; hemophilia; unstable angina pectoris; previous thoracotomy; previous spinal operation in the thoracic region; acute infection or

inflammation; traumatic TS pain; and pain caused by possible cardiac or esophageal conditions. Factors such as fibromyalgia, inflammatory diseases, malignant and systemic conditions were evaluated by physicians before enrolling in the study. Clinical examination was performed by two physical therapists with up to 6 years of experience in musculoskeletal physical therapy with continuous post-graduate education.

The intra- and inter-rater reliabilities of TS mobility and posture assessment have been estimated earlier in the same TS treatment study[25]. The exact methodology has been described elsewhere [25] but, briefly, upright and sitting postures of the TS were evaluated by visual inspection from a side-view by the therapist, and categorized as normal, decreased, or increased thoracic kyphosis (Figure 1a-b). The intra-rater reliability has been shown to be at least strong (kappa 0.78 and 0.87 in standing and sitting, respectively), whereas inter-rater reliability has been shown to be weak (kappa 0.28 and 0.23, respectively)[25]. Posture was assessed separately from Th1-Th6, Th6-Th12, and Th1-Th12. TS posture and mobility into flexion and extension were obtained in the sitting position using a Saunders® inclinometer (White Plains, NY, USA) and were reported in degrees (Figure 1c-h). Prior to the measurements the 7th cervical spine segment (C7), Th1, Th6, and Th12 were palpated and marked. The intra-rater reliability for posture has been shown to be at least strong (intraclass correlation coefficient [ICC] ranging from 0.74 to 0.84); and for mobility at least moderate in flexion (ICC 0.49–0.67); and weak to moderate in extension (ICC 0.30–0.46)[25]. The inter-rater reliabilities have been reported to be approximately similar to the inter-rater reliabilities for posture measurements (ICC 0.60–0.85). However, the inter-rater reliability was lower for flexion mobility (ICC 0.19–0.52) and higher for extension mobility (ICC 0.58–0.62) compared to the intra-rater reliabilities. In addition, upper (C7–Th5) and whole (Th1–Th12) TS flexion and whole TS extension (Th1–Th12) mobility while sitting were assessed by tape measurement and reported in millimeters (Figure 1i-l). The intra-rater ICC for these three measurements were 0.66, 0.72, and 0.30, respectively, whereas inter-rater ICC were 0.28, 0.74, and 0.29, respectively[25].

Self-reported thoracic pain intensity during the last week was evaluated using VAS (horizontal line) ranging from 0 to 100 mm and reported separately for maximum pain, average pain, and night pain. The total of TS pain scores was obtained by calculating the mean of the scores for average pain, maximum pain, and night pain. The duration of the TS pain was recorded in full weeks since the beginning of symptoms or a substantial increase in the intensity of chronic pain.

Figure 1. The assessment of thoracic spine (TS) posture and mobility. Visual inspection of TS: Normal kyphosis (a); increased thoracic kyphosis (b). Measurement of 1st thoracic spine segment (Th1) posture (c); Th6 posture (d); and Th12 posture using inclinometer (e). Measurement of Th1 flexion (f); Th6 flexion (g); and Th6 extension using inclinometer (h). The actual inclination of the thoracic spine was calculated based on these values for the upper (Th1-6), lower (Th6-12) and whole TS (Th1-12). Measurement of 7th cervical spine (C7) to Th5 in neutral position using tape measure (i). Measurement of C7-T5 flexion (j); Th1-12 flexion (k); and Th1-12 extension using tape measure (l).

Statistical analysis

The sample size of the study was calculated with statistical power of 0.80 and probability level of 0.05 when there are two independent predictors in the regression model and the effect size was anticipated to be 0.15. According to the calculation, the minimum sample size was 67 participants[26]. Descriptive statistics are presented as mean, standard deviation (SD), and range for normally distributed variables. The correlation coefficients were calculated by Spearman's rank correlation to evaluate the strength and direction of the relationship between different clinical TS assessment methods. Correlations were classified as very weak (0.01 to 0.19),

weak (0.20–0.39), moderate (0.40–0.59), strong (0.60–0.79), and very strong (≥0.80)[27]. Differences between females and males were tested with the independent t-test and Mann-Whitney U-test for parametric and nonparametric data, respectively. Variables of TS posture and mobility obtained by the inclinometer and tape measurement were categorized into three groups: the lowest quartile (25% of the participants), two middle quartiles (50% i.e. interquartile), and the highest quartile groups (25%). The interquartile range was considered as the reference group and multinomial logistic regression was used to analyze the association of the pain variables with TS posture and

mobility. The multinomial logistic regression model was adjusted for age. Multinomial logistic regression analysis was used as the dependent variables were classified into three groups and no linear relationship was found and, thus, results are shown in odds ratios (OR). For all statistical analyses, IBM SPSS Statistical software, version 23 (Chicago, IL, USA) was used.

Results

There were a total of 73 participants in the study, 21 (29%) males and 52 (71%) females (Table 1). The mean age of the participants was 39 years (range 22–56) and mean body mass index (BMI) was 24.8 kg/m^2 (range 17.1–37.0). The means of pain intensities, calculated for both sexes, are presented in Table 1.

The correlation matrix depicting the relationships between posture and mobility is shown in Table 2. The correlation between sitting and upright TS postures evaluated by inspection was very strong (correlation coefficient, $\rho = 0.90$). There was a strong correlation in the inclinometer readings between both Th1-Th6 and Th1-Th12 regions, and TS postures evaluated by inspection in the sitting ($\rho = 0.61$ and 0.66, respectively) and upright postures ($\rho = 0.60$ and 0.61, respectively). There were weak to moderate negative correlations between the mobility and posture variables, such as between Th1-Th6 flexion obtained by an inclinometer and both TS postures evaluated by inspection ($\rho = -0.38$) and Th1-Th12 posture obtained by the inclinometer ($\rho = -0.44$). Thoracic flexion (Th1-Th12) correlated moderately with lower thoracic (Th6-Th12, $\rho = -0.40$) and whole thoracic (Th1-Th12, $\rho = -0.45$) postures but not with upper thoracic (Th1-Th6, -0.26) posture (obtained by inclinometer). Inclinometer and tape measures correlated moderately between flexion and extension positions (Table 2).

The results of the final model (after adjusting for age) between pain, posture, and mobility variables in the three groups (the lowest quartile, interquartile, and the highest quartile) are shown in Table 3. The posture measurement obtained by inclinometer revealed that the less kyphotic upper TS (Th1-Th6) and whole TS were associated with less night pain (OR 0.96; 95% confidence interval [CI] 0.94–0.99, and OR 0.97; 0.95–1.00, respectively). Moreover, the less kyphotic whole TS was associated with less pain sum score (OR 0.96; 0.92–1.00). The greater flexion mobility of the upper (Th1-Th6) and lower (Th6-Th12) TS were associated with less pain sum score (OR 0.96; 0.91–1.00 and OR 0.96; 0.91–1.00, respectively). Furthermore, greater upper (Th1-Th6) TS flexion was associated with lower reported worst pain (OR 0.95; 0.92–0.99). Diminished extension of the upper (Th1-

Th6) TS was significantly associated with higher worst pain (OR 1.04; 1.00–1.07) and whole TS with pain sum score (OR 1.05; 1.01–1.08).

Discussion

To our knowledge, our study is the first to evaluate the association between TS pain, and posture and mobility among adult and working-age participants (18–55 years) in a clinical setting. The findings showed that reduced thoracic extension was associated with higher pain scores among participants with thoracic pain. In addition, increased flexion in the upper and lower TS measured by an inclinometer was associated with lower pain scores. We also found a flat upper TS and whole TS to be associated with significantly lower pain at night, and a flat whole TS with pain sum score. Visual inspection of posture by physical therapists was strongly correlated with the measured upper and whole thoracic posture. Thoracic flexion had a moderate negative correlation with lower and whole thoracic postures obtained by an inclinometer, suggesting that participants with less kyphotic TS had higher TS flexion mobility.

Studies assessing adult patients with TS pain and TS posture and/or mobility are scarce. Risk factors have usually been explored among the general working population, not patients with TS pain [4,7]. The majority of studies assessing the association of TS posture or mobility with symptoms have enrolled either postmenopausal women, older adults, or athletes [21–23]. It is essential to produce data concerning adult workers with clinically meaningful TS pain as their symptoms impair productivity, and sick leaves affect the economy negatively. In addition, studies usually evaluate hyperkyphosis without a proper assessment of decreased kyphosis, i.e. hypokyphosis of the TS.

Although information about TS pain is scarce, there are a few studies assessing TS pain with TS posture or mobility. Ryan et al [5]. showed greater thoracic kyphosis to be associated with TS pain and Ensrud et al [6]. with upper and middle back pain among osteoporotic postmenopausal women. Thoracic kyphosis has been shown to be associated with interscapular pain[28]. Increased thoracic kyphosis has also been reported to limit daily functioning in older populations[29]. Decreased TS mobility has been shown to be associated with low back pain [18,30]. We found reduced TS extension mobility to be associated with greater TS pain and increased thoracic flexion mobility to be indicative of lesser pain among participants with TS pain. However, the association with reduced thoracic extension was not systematically found in all our measurements. Spinal degenerative changes may decrease the mobility of the TS [1] and therefore can be one factor causing upper back pain.

Table 1. Study participants' characteristics, pain, and thoracic spine (TS) posture and mobility variables classified by sex.

Variables	Female	Male	Total	P value*
Participants	52 (71)	21 (29)	73 (100)	
Age[#]	38.4 (9.2)	39.7 (8.2)	38.7 (8.9)	0.58
Height (cm)**	164 (161–167)	179 (176–186)	166 (162–169)	<0.001
Weight (kg)**	65.0 (60.0–68.5)	81.3 (76.0–94.0)	68.0 (62.3–78.0)	<0.001
BMI**	23.4 (21.6–26.0)	25.3 (23.4–27.5)	24.1 (22.5–26.7)	0.024
Pain variables				
Night pain[#]	39.8 (25.1)	47.9 (17.9)	42.1 (23.5)	0.13
Average pain[#]	44.1 (17.2)	45.4 (18.2)	44.5 (17.4)	0.79
Worst pain[#]	55.9 (19.2)	60.5 (17.6)	57.2 (18.7)	0.34
Pain sum[#]	46.6 (15.8)	51.2 (15.3)	47.9 (15.7)	0.26
Pain duration (weeks)**	12 (8–24)	20 (8–40)	12 (8–25)	0.15
Thoracic spine inclination measurement in degrees**				
Th1-6 posture	21 (15.5, 27.5)	32 (20, 32)	22 (17.50, 29)	0.82
Th6-12 posture	9 (7, 12)	10 (8.5, 15.5)	9 (7.5, 12.5)	0.10
Th1-12 posture	30 (21.75, 38.75)	36 (31, 43)	33 (26, 39.5)	0.02
Th1-6 flexion	16.5 (12.25, 22.75)	15 (12, 17)	16 (12, 20.5)	0.30
Th6-12 flexion	10 (5.25, 13)	11 (9.5, 15.5)	10 (7, 14)	0.16
Th1-12 flexion	26 (19.25, 33)	28 (22, 30.5)	26 (21, 32)	0.87
Th1-6 extension	11 (4, 17.25)	13 (8, 18.5)	11 (5.5, 18)	0.21
Th6-12 extension	6 (2.25, 9)	12 (7, 17.5)	7 (3, 12)	<0.01
Th1-12 extension	16 (10, 24.75)	25 (20, 32)	20 (12, 26.5)	<0.01
Thoracic spine tape measurement in centimeters**				
C7-Th5 flexion	2.7 (2.5, 3.2)	3.0 (2.5, 3.1)	2.8 (2.5, 3.2)	0.53
Th1-Th12 flexion	40.0 (34.25, 48.5)	43.0 (36.0, 56.0)	40.0 (35, 51.5)	0.31
Th1-Th12 extension	21.5 (12.25, 34.0)	29.0 (22.5, 39.0)	25.0 (15, 35)	0.01

* Difference between sex
Continuous variables are presented as [#] mean (SD) or ** median (interquartile range, IQR) and categorical as number (%).
Statistical analysis: [#]independent t-test, *Mann-Whitney U test
BMI, body mass index
Th1-6, from 1st to 6th TS segment
C7, 7th cervical spine segment

Altered postural changes can influence spinal muscle activity [31] and therefore could be reasoned to affect spinal mobility. When considering spinal sagittal balance, postural changes, possibly compensatory, can lead to increased trunk muscle activity[32]. Genetic correlations have been found between thoracic kyphosis and both paraspinal muscle area and density[33], suggesting a relationship between thoracic posture and muscle function. However, the mobility of the spinal functional unit is also determined by other structural factors, such as intervertebral discs and zygapophyseal joints [1,34]. Thoracic spinal stiffness may compensatorily increase the mobility of the cervical and lumbar spines[1]. As the spine functions as a unit, excessive thoracic kyphosis could be compensated by excessive lumbar and cervical lordosis. In addition to TS, altered thoracic posture or mobility can cause symptoms in the cervical and lumbar regions as well.

Thoracic kyphosis is affected by age [9,10]; excessive kyphosis can therefore have different implications depending on the participant. Hyperkyphosis can have various origins; it can be congenital in nature [11,12], it could be due to poor habitual posture[1], degenerative spinal conditions[8], or general conditions such as osteoporosis[15]. During clinical examination, a participant can easily alter his/her habitual spinal posture given the unnatural circumstances of a clinical examination. However, we evaluated TS postures by visual inspection, while participants were sitting and standing upright, and there was a good correlation between them. We have earlier reported

a strong to very strong intra-rater reliability for a visual inspection postural evaluation in sitting and standing positions[25].

Usually, inspection and hands-on examination are one of the key features when clinically examining patients. Our purpose was to evaluate the value of clinical examination and the association of these factors with TS pain. Previously, we have found strong intra- and inter-rater reliabilities of TS mobility and posture evaluation. [25] The results of this study suggest that the clinician's evaluation of thoracic posture seems appropriate and valid in a clinical examination of patients with TS pain. However, TS flexion and extension mobility should also be examined. As we found flexion and extension of TS to affect pain factors, there may be an indication for manual and exercise therapy when hypomobility of the TS is present.

The Cobb method was originally developed to assess scoliosis[35], but it is also used to evaluate thoracic kyphosis[9]. This method has been found to be a valid and reliable measure for thoracic regions [36,37]. Cobb method is evaluated from radiographs and, thus, exposes individuals to radiation and is time consuming[38]. Therefore, safe, quick, accessible, user-friendly, and reliable evaluation methods are required in clinical practice. We found strong correlations between the physical therapist's visual inspection of the TS posture and both upper and whole-thoracic posture obtained by an inclinometer. Our results encourage clinicians to use posture evaluation when examining patients with TS pain. We have previously

Table 2. The correlation matrix of posture and mobility variables.

Outcome measure	Visual inspection of the thoracic posture					Inclinometry (sitting position)						Range of motion, tape measure		
	Sitting position	Upright position	Th1-Th6 posture	Th6-Th12 posture	Th1-Th12 posture	Th1-Th6 flexion	Th6-Th12 flexion	Th1-Th12 flexion	Th1-Th6 extension	Th6-Th12 extension	Th1-Th12 extension	C7-Th5 flexion	Th1-Th12 flexion	Th1-Th12 extension
Visual inspection of the thoracic posture														
Sitting position	1													
Upright position	0.90*	1												
Inclinometry (sitting position)														
Th1-Th6 posture	0.61*	0.60*	1											
Th6-Th12 posture	0.26*	0.18	0.06	1										
Th1-Th12 posture	0.66*	0.61*	0.82*	0.55*	1									
Th1-Th6 flexion	−0.38*	−0.24*	−0.28*	−0.40*	−0.44*	1								
Th6-Th12 flexion	−0.21	−0.21	−0.13	−0.23*	−0.24*	0.08	1							
Th1-Th12 flexion	−0.35*	−0.24*	−0.26*	−0.40*	−0.45*	0.71*	0.60*	1						
Th1-Th6 extension	−0.10	−0.08	0.27*	0.11	0.23	−0.03	0.12	0.04	1					
Th6-Th12 extension	0.02	0.08	0.04	0.22	0.12	0.06	0.24*	0.20	0.11	1				
Th1-Th12 extension	−0.06	0.03	0.24*	0.21	0.28*	0.07	0.25*	0.16	0.73*	0.60*	1			
Range of motion, tape measure														
C7-Th5 flexion	0.09	0.06	0.20	0.12	0.22	0.08	−0.02	0.00	0.04	0.00	0.08	1		
Th1-Th12 flexion	−0.16	−0.14	−0.10	−0.15	−0.21	0.53*	0.53*	0.69*	0.08	0.27*	0.19	0.26*	1	
Th1-Th12 extension	−0.20	−0.17	−0.09*	0.02	−0.04	0.11	0.46*	0.33*	0.32*	0.47*	0.53*	0.01	0.28*	1

Th1, 1st thoracic spine segment
C7, 7th cervical spine segment
* p-value <0.05

Table 3. The association of thoracic spine pain variables with different thoracic posture and mobility variables in three groups after adjusting for age[§].

Variable	Night pain		Average pain		Worst pain		Pain sum	
	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
Sitting position[#]								
Decreased kyphosis	1.00	0.98–1.02	0.98	0.95–1.01	0.98	0.96–1.01	0.98	0.95–1.01
Normal[$]	–		–		–		–	
Increased kyphosis	1.02	0.98–1.05	0.98	0.94–1.03	0.99	0.95–1.03	1.00	0.95–1.02
Upright position[#]								
Decreased kyphosis	1.00	0.98–1.02	0.99	0.96–1.02	1.00	0.97–1.03	0.99	0.96–1.03
Normal[$]	–		–		–		–	
Increased kyphosis	1.06	1.00–1.12	1.00	0.95–1.05	1.00	0.95–1.05	1.03	0.97–1.10
Th1-6 posture, incl								
Lower quartile	0.96*	0.94–0.99	0.99	0.95–1.02	1.00	0.97–1.03	0.96	0.92–1.01
Interquartile[$]	–		–		–		–	
Higher quartile	0.98	0.96–1.01	1.01	0.98–1.04	1.03	0.99–1.06	1.01	0.97–1.05
Th6-12 posture, incl								
Lower quartile	0.98	0.96–1.01	1.01	0.97–1.04	0.99	0.96–1.02	0.98	0.95–1.03
Interquartile[$]	–		–		–		–	
Higher quartile	0.98	0.96–1.01	1.01	0.97–1.04	0.99	0.96–1.03	0.99	0.95–1.03
Th1-12 posture, incl								
Lower quartile	0.97*	0.95–1.00	0.98	0.94–1.01	0.98	0.95–1.01	0.96*	0.92–1.00
Interquartile[$]			–		–		–	
Higher quartile	0.98	0.95–1.01	1.00	0.97–1.03	1.02	0.99–1.06	1.00	0.96–1.03
Th1-6 flexion, incl								
Lower quartile	1.00	0.97–1.03	0.99	0.96–1.03	1.00	0.97–1.03	1.01	0.97–1.05
Interquartile[$]	–		–		–		–	
Higher quartile	1.00	0.97–1.03	0.99	0.96–1.03	1.00	0.97–1.03	0.96*	0.91–1.00
Th6-12 flexion, incl								
Lower quartile	1.00	0.98–1.03	1.02	0.99–1.05	0.99	0.96–1.02	1.01	0.97–1.05
Interquartile[$]	–		–		–		–	
Higher quartile	0.99	0.96–1.02	0.97	0.93–1.01	0.95*	0.92–0.99	0.96*	0.91–1.00
Th1-12 flexion, incl								
Lower quartile	1.03	0.98–1.03	1.04	0.97–1.04	1.00	0.97–1.03	1.00	0.96–1.04
Interquartile[$]	–		–		–		–	
Higher quartile	1.01	0.95–1.04	0.99	0.95–1.02	0.99	0.95–1.02	1.00	0.96–1.04
Th1-6 extension, incl								
Lower quartile	0.98	0.96–1.01	1.03	0.99–1.06	1.04*	1.00–1.07	1.02	0.98–1.06
Interquartile[$]	–		–		–		–	
Higher quartile	1.01	0.98–1.04	1.01	0.98–1.05	1.03	0.99–1.07	1.03	0.99–1.08
Th6-12 extension, incl								
Lower quartile	1.02	0.99–1.05	1.03	1.00–1.06	1.01	0.98–1.04	1.03	0.99–1.07
Interquartile[$]	–		–		–		–	
Higher quartile	1.01	0.99–1.04	1.00	0.96–1.03	0.99	0.96–1.03	1.01	0.97–1.05
Th1-12 extension, incl								
Lower quartile	1.00	0.97–1.02	1.02	0.99–1.06	1.03	1.00–1.07	1.02	0.98–1.06
Interquartile[$]	–		–		–		–	
Higher quartile	1.00	0.97–1.02	0.99	0.95–1.03	1.01	0.98–1.05	1.00	0.96–1.04
C7-Th5 flexion, tape m								
Lower quartile	1.00	0.97–1.02	0.98	0.95–1.01	1.01	0.98–1.04	1.00	0.96–1.03
Interquartile[$]	–		–		–		–	
Higher quartile	0.97	0.95–1.00	0.99	0.96–1.03	1.00	0.97–1.03	0.98	0.93–1.02
Th1-12 posture, tape m								
Lower quartile	1.00	0.97–1.03	1.02	0.98–1.05	1.00	0.97–1.03	1.01	0.97–1.05
Interquartile[$]	–		–		–		–	
Higher quartile	1.01	0.98–1.03	1.03	0.99–1.07	1.01	0.98–1.05	1.03	0.99–1.07
Th1-12 flexion, tape m								
Lower quartile	1.01	0.98–1.03	1.02	0.98–1.05	1.00	0.97–1.04	1.02	0.98–1.05
Interquartile[$]	–		–		–		–	
Higher quartile	1.00	0.97–1.02	1.01	0.98–1.05	0.99	0.96–1.02	1.00	0.96–1.04
Th1-12 extension, tape m								
Lower quartile	1.03	1.00–1.06	1.03	0.97–1.11	1.03	0.96–1.10	1.05*	1.01–1.08
Interquartile[$]	–		–		–		–	
Higher quartile	0.99	0.96–1.01	0.98	0.95–1.02	1.02	0.98–1.05	0.99	0.95–1.03

[§]Three groups were divided as follows: the lowest quartile (i.e. decreased kyphosis), interquartile (normal), and the highest quartile (i.e. increased kyphosis)

[#]Therapist's visual inspection

[$]Reference group

* Significant associations, after rounding up/down lower/upper limit of 95% confidence interval equals 1.00.

OR, odds ratio; CI, confidence interval; Th, thoracic spine segment; incl, inclinometer; tape m, tape measure

found moderate to good reliability for inclinometer and tape measure assessments for posture and flexion mobility, however, the reliability of extension mobility is still questionable[25].

Our study consisted of participants with TS pain with a good representation of the working age population containing both men and women. Therefore, we believe these results can be better generalized to populations at

large compared to the previous studies on older adults, asymptomatic participants, or athletes. Furthermore, we wanted to exclude participants with mild TS pain in order to analyze patients with clinically more meaningful TS pain as usually studies assessing general or working population include participants with any TS pain [3,7].

We excluded participants with very mild pain, with either mean pain, maximum pain, or night pain being equal to or less than 25 mm during the last week. Using these criteria, our purpose was to include only participants with constant pain affecting night and day and everyday life, i.e. participants with clinically meaningful pain. Moreover, spinal pain is shown to be associated with difficulties at night and sleeping problems[39].

There are a few limitations in this study. Only TS was considered in postural evaluation. Pain variables were enquired for the last week, and since participants had experienced TS pain for rather long time, variables that provided information on participants' symptoms for a longer period could have been useful. However, it could have increased a recall error. Moreover, we inquired only factors associated with pain and not function. Even though TS pain has been associated with function[3], future studies with higher number of participants should consider disability more comprehensively. Moreover, due to the quite small sample size, we were not able to carry out the ordinal logistic regression analyses and, therefore, find more precise risk estimation for TS pain in TS posture or mobility. In addition, due to the small sample size, the risk for having higher TS pain with lower or higher TS posture or mobility values remained quite low (from 3 to 6%) and, therefore, the clinical value remains unclear. There may be differences in mobility and mobility patterns of coupled movements in the TS between women and men [40], but, unfortunately, our study lacked the power to analyze it. However, we did not find any significant differences in TS pain between the sexes. The strength of this study is that the current study assessed TS posture and mobility among adult participants with TS pain for the first time, given that this group's inability to workplaces is the highest burden on the economy. Moreover, we used comprehensive exclusion criteria for possible confounding factors for TS pain.

Conclusion

In this study comprising adult participants with TS pain, reduced thoracic extension mobility was associated with higher pain scores. Moreover, greater TS flexion was associated with lower pain scores. Flat upper TS was associated with significantly lower night pain and pain sum score. The physical therapist's evaluation of thoracic posture seemed to correlate strongly with the measured upper and whole thoracic posture. More research is required to demonstrate the clinical importance of thoracic posture and mobility and their association with symptoms and preferably with larger number of participants.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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