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The variations of scapular alignment between individuals with and without scapulocostal syndrome

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Abstract

Scapulocostal syndrome (SCS) is a chronic pain condition indicating signs of muscle imbalance which may cause scapular alignment alterations. However, scapular alignment in SCS patients has not yet been investigated. This study aimed to explore the variations of scapular alignment between individuals with and without SCS. Thirty-nine individuals with SCS were matched with thirty-nine healthy individuals. Both groups were assessed for scapular alignment using the scapular position estimator program on selected outcomes. The results showed that SCS patients demonstrated significantly lower values in shoulder flexion on the right side of the body than the healthy group in lower horizontal distance at 30° (SCS; 90.73 millimeters; mm, healthy; 98.63 mm; $p = 0.029$), 60° (SCS; 101.44 mm, healthy; 110.12 mm; $p = 0.005$), 90° (SCS; 112.79 mm, healthy; 121.10 mm; $p = 0.005$), 120° (SCS; 117.45 mm, healthy; 124.85 mm; $p = 0.006$), 150° (SCS; 117.95 mm, healthy; 124.39 mm; $p = 0.014$), and 180° (SCS; 119.26 mm, healthy; 125.53 mm; $p = 0.034$). Moreover, SCS patients displayed significantly lower values in shoulder flexion on the right side than the healthy group in the upward rotation angle, superior translation angle, and external rotation angle ($p < 0.05$). In shoulder abduction, SCS patients demonstrated significantly lower values amid lower horizontal distance, superior translation angle, and external rotation angle on the right side than the healthy group ($p < 0.05$). These findings indicated that scapular alignment in individuals with and without SCS differed. Scapular positions of SCS patients tended to be scapular dyskinesis.

Keywords: Muscle imbalance, Scapular dyskinesis, Scapular malalignment, Scapular position, Scapulocostal syndrome

1. Introduction

Scapulocostal syndrome (SCS) is a common chronic pain at the upper back and scapular region. Pain may be radiated to other areas, such as the neck, shoulder, visceral structure, and anterior chest wall [1,2]. SCS is similar to myofascial pain syndrome; it exhibits myofascial trigger points (MTrPs) as a unique sign, appearing in SCS also [3]. Previous studies found various groups of muscles involved with MTrPs around the scapular region such as the levator scapulae, trapezius, rhomboid, teres, serratus anterior, and serratus posterior superior muscles [4,5]. Although pain around the scapula is the hallmark of SCS, scapular malalignment may be linked to SCS pain [6].

Chronic cases of SCS can affect motor function and some cases were found to include muscle weakness. According to Janda's concept, interscapular muscles are prone to weakness due to prolonged reciprocal inhibition signaling from the ventral muscles, especially the pectoral muscles. Muscle weakness at the scapula, shoulder, and arm may occur. In consideration of activities of daily living, the most common employment among new generations are information technology-based positions in an information technology orientated society which consist of prolonged durations in the same position i.e., typing on a computer, using mobile phones, and prolonged static positions in some careers (e.g., dentists and office workers). These factors may promote muscle imbalance of the upper back or upper crossed syndrome. It shows tightness of the pectoral and neck extensor muscles, whereas weakness of the neck flexors and interscapular muscles may occur simultaneously [7]. The weakness is usually caused by guarding, without atrophy or neurophysiologic evidence of denervation amid electromyography [1]. Weakness usually involves the scapular stabilizers that consist of the trapezius and serratus anterior muscles. In addition, weakness of the levator scapulae or rhomboids is presented with MTrPs [4,8].

Scapular malalignment can be referred to as scapular dyskinesis (SD). This is a general term used to describe the loss of control of normal scapular physiology, mechanics, and motion. SD has been associated with shoulder impingement syndrome, rotator-cuff tendinopathy, and multidirectional impairments [9]. The signs of SD are medial border prominence or inferior angle prominence, early scapula elevation or shrugging during arm elevation, and abnormal scapulohumeral rhythm during arm elevation or lowering. The most common causative mechanisms of SD involve alterations in the soft tissues around the scapula [10]. From the literature review, the muscle imbalance in the scapular plane is involved in the muscle imbalance of SCS as these signs of both syndromes exhibit intersectional problems. The overlapped muscles involved with muscle imbalance between these conditions consist of the tightness of the levator scapulae and pectoralis minor muscles, as well as weakness of the serratus anterior and lower trapezius muscles [11,12].

Muscle imbalance amid scapular rotation force leads to muscular activation pattern alterations. A previous report investigated electromyography (EMG) patterns and muscle imbalance patterns in athletes with shoulder pain. The overhead athletes with shoulder pain showed a significant increase in upper trapezius muscle activation. On the other hand, the results represented a decrease in serratus anterior and lower trapezius activation [13]. Another study reported that the athletes with shoulder impingement syndrome had a significant decrease in lower and middle trapezius muscle activation, as well as increased activation levels of the upper trapezius muscle [14]. These findings are congruent with muscle imbalance according to Janda's concept in which the serratus anterior and lower trapezius are most prone to weakness with the upper trapezius prone to tightness [7]. Muscle imbalances may be the source of differences in scapular alignment between individuals with SCS and healthy individuals. The systematic review reported that scapular malalignment was found to have a greater presented prevalence (61%) in overhead athletes compared with non-overhead athletes (33%) [15]. Another study reported that patients with a high ergonomic risk level indicated scapular malalignment [16]. Furthermore, a high level of smartphone addiction induces scapular malalignment [17]. Although previous studies have investigated scapular alignment among several conditions, the relationship between SCS and scapular malalignment is unclear. The identification of the co-incidence of SCS is an important factor for clinical management. Therefore, the objective of this study was to explore the variations in scapular alignment between individuals with and without SCS.

2. Materials and methods

2.1 Study design

This study was a cross-sectional study, conducted from December 2020 to May 2021. All participants signed a consent form prior to participating in the study procedures.

2.2 Participants

We enrolled adult participants consisting of both SCS patients and healthy controls via a bulletin board and social media in Khon Kaen province. In both groups, health history and physical characteristics were examined by a physiatrist at Srinagarind Hospital to confirm diagnosis of SCS and define healthy subjects. Inclusion criteria in the SCS group was as follows: male or female aged between 18 and 50 years, experiencing pain at the scapular region for longer than 12 weeks (visual analog scale; VAS equal or more than 5 centimeters), discovery of at least latent MTrPs in the muscles around the scapular region, including levator scapulae, trapezius, rhomboid, teres, and serratus posterior superior muscles. In the healthy group, individuals with no history of SCS throughout the year prior were enrolled in the study. Both groups were age, gender, and body mass index matched. Individuals with degenerative shoulder joint disease, cervical radiculopathy with facet joint dysfunction and/or intervertebral disc-herniation, rotator-cuff disease, or adhesive shoulder capsulitis were excluded.

2.3 Sample size calculation

The sample size was calculated via an outcome (external rotation angle) from a previous study [18]. They reported the association between scapular dyskinesis and shoulder pain in young adults. In this study, 30 sedentary young adults of both genders, aged 20-35 years were evaluated. The sample was divided into two groups with an equal number of subjects, one group with shoulder pain (n= 15) and the other pain-free (n= 15). The external rotation angle in the shoulder pain group (the right side) was 9.61 degrees with standard deviation of 5.93, and the external rotation angle in the shoulder pain group (the left side) was 6.15 degrees with standard deviation of 4.83. A pooled variance estimate (σ^2) for calculating the sample size was applied to calculate as follows:

$$\sigma^2 = \frac{(n_1-1)(s_1)^2+(n_2-1)(s_2)^2}{n_1+n_2-2} \quad (1)$$

The pooled variance estimate (σ^2) for calculating the sample size was 29.25 and ($\mu1$ - $\mu2$) was 3.46 degrees [18]. The significance level of lower than 0.05 ($Z_{\alpha/2(0.025)} = 1.96$) and a power of test at 80% ($Z_{\beta\,(0.1)} = 0.84$) were used to calculate as follow:

$$n/\,group = \frac{2\sigma^2(Z_\alpha + Z_\beta)^2}{(\mu_1 - \mu_2)^2} \quad (2)$$

A total of 39 patients with SCS as well as another 39 healthy participants were included.

2.4 Procedures

Following informed consent, participants provided demographic information consisting of age, gender, weight, height, types of exercise partaken in, and self-reported hand dominance. In the SCS group, participants completed the VAS, aggravating factors, and duration of scapular pain. The affected muscle presenting MTrPs was examined by the physical therapist. Then, the physical therapist assessed pressure pain threshold in accordance with their MTrPs.

In the assessment of scapular alignment, female participants were asked to wear tank tops and males shirtless. Adhesive markers were placed on the landmarks of both acromion processes, superior angles, and inferior angles. In addition, the inclinometers were attached on both of participants' arms for motion identifying. The participants were instructed to stand comfortably in a normal standing position and to look straight ahead at a predetermined point on the foot template. The position of the scapulae was recorded with a webcam camera. The webcam camera was attached to a tripod stand placed 1 meter behind each participant for clear focus. In this study, the physical therapist used a horizontal stand with a water-based horizontal line to calibrate the horizontal line. The participants were asked to actively flex and abduct the shoulders to varying degrees i.e., 0°, 30°, 60°, 90°, 120°, 150°, and 180°, with each angle corrected as necessary by a physical therapist. The scapular position estimator program was employed to calculate the positions of the scapulae. Each position was repeated twice with a 2 min rest between times with average value taken for analysis. The procedures were under the control of the physical therapist. This measurement was shown to have good intra-reliability (intraclass correlation coefficients; ICC= 0.82-0.98).

Outcome measures in the software consisted of 5 variables: firstly, lower horizontal distance is the distance from the inferior angle of the scapula perpendicular to the spinous process (millimeter; mm) (Figure 1A). Secondly, upper horizontal distance is the distance from the root of the spine to the spinous process (mm) (Figure 1B). Thirdly, upward rotation angle is measured as the angle between the acromion process to the root of the spine and the vertebral axis (C7-T7) (Figure 1C). Fourthly, superior translation angle is the angle between the line from the acromion process to the midpoint of the spinous process of the C7 vertebra and the vertebra axis (C7-T7) (Figure 1D). Finally, external rotation angle is the angle between the longitudinal line in the direction of the spinal column and the line joining the superior and inferior angles of the scapula (Figure 1E) [18-22]. Figure 1 was drafted by the authors.

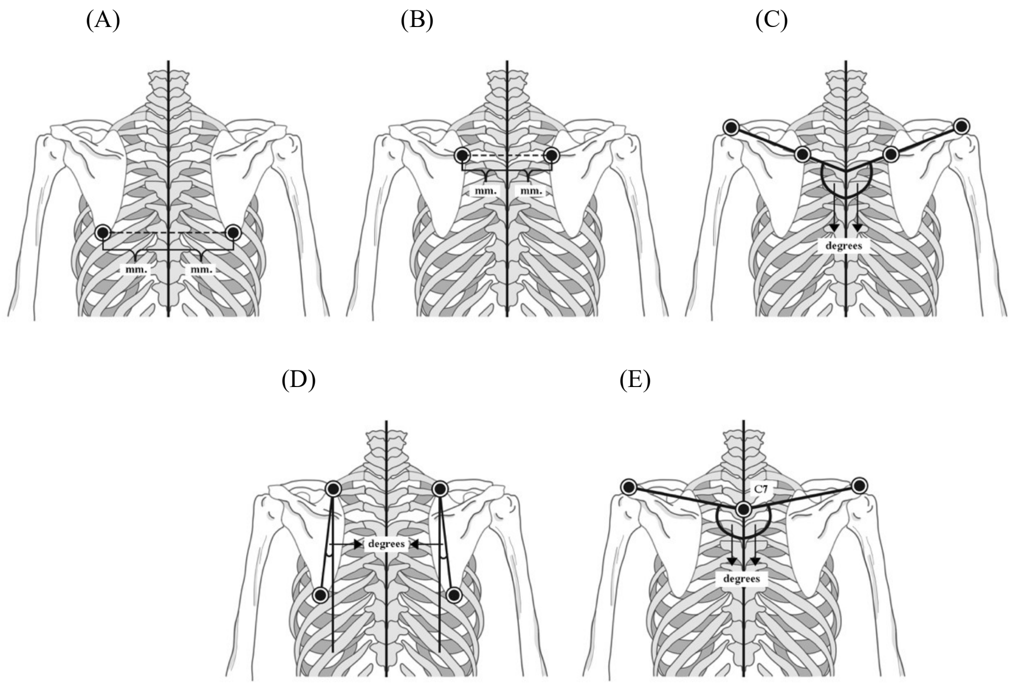

Figure 1 Outcomes of scapular alignment in which (A) signifies lower horizontal distance, (B) upper horizontal distance, (C) upward rotation angle, (D) superior translation angle, and (E) external rotation angle.

2.5 Statistical analysis

Demographic data were shown as mean and standard deviations. The Shapiro-Wilk test was utilized to determine normal distribution of data. Independent sample t-test was employed to compare all outcome measures between individuals with and without SCS if data are normally distributed. The level of statistical significance was set at $p < 0.05$. SPSS version 23 (SPSS Inc., Chicago, IL, USA) employed for data collection and analysis.

3. Results

A total of 101 participants responded to the recruitment and were screened by a physiatrist. In the SCS group, 4 participants were excluded due to a VAS lower than 5 centimeters, while an additional 6 participants were excluded due to the presentation of adhesive capsulitis (n = 3) and cervical radiculopathy (n = 3). In the healthy group, 13 participants were excluded resultant of age, gender, and body mass index not being matched to SCS participants (Figure 2). Thus, 78 subjects participated in the study and were categorized as SCS patients (39 individuals; 50%) and healthy control subjects (39 individuals; 50%). Baseline characteristics between both groups were comparable in terms of age, gender, body mass index, exercise factors, and dominant arm (Table 1). In the SCS group, the predominant cause of scapular pain was prolonged sitting at a computer during work (at least 30 hours per week) (n = 21; 54%). The MTrPs of SCS group were discovered in the levator scapulae (n = 14; 36%), upper trapezius (n = 10; 26%), serratus anterior (n = 9; 23%), and rhomboid muscles (n = 6; 15%). The affected sides were at the right side (n = 30; 77%) and the left side (n = 9; 23%). Average pain intensity according to VAS revealed 6.12 ± 0.74 centimeters with 16.44 ± 13.40 months of duration of scapular pain. Pressure pain threshold at MTrPs represented 1.53 ± 0.52 kg/cm^2.

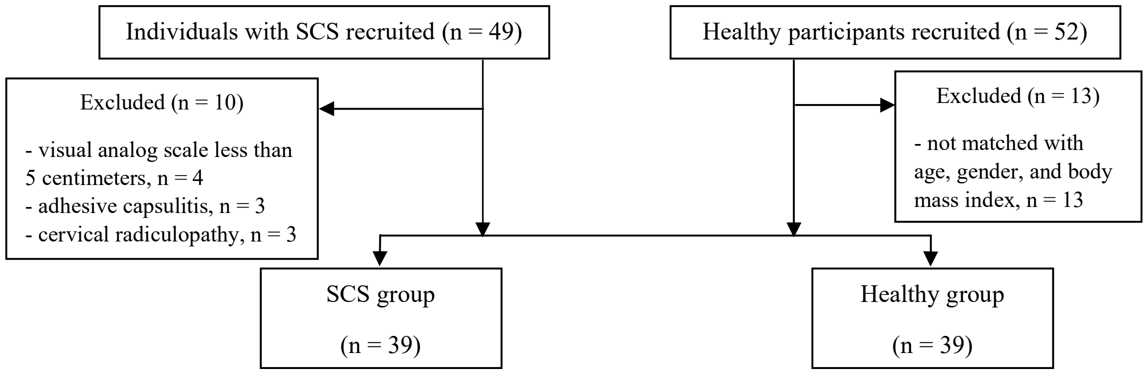

Figure 2 A study-flow to show the enrollment of patients with scapulocostal syndrome (SCS) and healthy control in the study.

Table 1 Baseline characteristics of patients with scapulocostal syndrome (SCS) and healthy group.

Characteristics	SCS (n=39)	Healthy (n=39)	*p*-value
Gender (male: female)	16 (41%): 23 (59%)	16 (41%): 23 (59%)	0.999[b]
Age (years); mean±SD	26.33±4.34	26.33±4.34	0.999[a]
Weight (kg); mean±SD	56.86±9.03	57.10±9.70	0.640[a]
Height (cm); mean±SD	165.21±9.41	165.56±9.30	0.909[a]
Body Mass Index (kg./m^2); mean±SD	20.72±1.67	20.61±1.60	0.764[a]
Exercise (n)			
Yes	21 (54%)	28 (72%)	0.101[b]
No	18 (46%)	11 (28%)	
Types of exercise (n)			
Jogging or walking	10 (48%)	17 (61%)	0.335[b]
Weight-training	8 (38%)	9 (32%)	
Badminton	2 (10%)	2 (7%)	
Boxing	1 (4%)	0 (0%)	
Dominant arm; n (%)			
Right	39 (100%)	39 (100%)	0.999[b]
Left	0 (0%)	0 (0%)	

Notes: The data are presented using mean ± standard deviation (SD) and n (%). [a] the differences between the SCS group and healthy group were compared using independent t-tests with the level of varying significance set at $p < 0.05$; [b] the variations between the SCS group and healthy group were compared utilizing the chi-square test with the level of significant difference set at $p < 0.05$.

To identify the variances in scapular alignment between individuals with and without SCS in varying positions of shoulder flexion and abduction, the comparison of scapular alignment variables including lower horizontal distance, upper horizontal distance, upward rotation angle, superior translation angle, and external rotation angle between both groups were analyzed. On comparing shoulder flexion position between groups, a significant difference was brought to light at 30° ($p = 0.029$), 60° ($p = 0.005$), 90° ($p = 0.005$), 120° ($p = 0.006$), 150° ($p = 0.014$), and 180° ($p = 0.034$) on the right side in the lower horizontal distance. In the upward rotation angle, a significant difference was discovered at 150° ($p = 0.046$) and 180° ($p = 0.025$) on the right side. In the superior translation angle, a significant difference was found at 30° ($p = 0.019$), 60° ($p = 0.008$), 90° ($p = 0.003$), 120° ($p = 0.041$), and 180° ($p = 0.029$) on the right side. Moreover, a significant difference was observed at 30° ($p = 0.026$), 60° ($p = 0.009$), 90° ($p = 0.005$), and 120° ($p = 0.012$) on the right side in the external rotation angle. On the other hand, there were no significant differences between groups in upper horizontal distance (Table 2).

In the course of comparing shoulder abduction position between groups, a significant difference was observed at 60° ($p = 0.001$), 90° ($p = 0.019$), 120° ($p = 0.018$), and 180° ($p = 0.046$) on the right side amid lower horizontal distance. In the superior translation angle, a significant variance was discovered at 30° ($p = 0.018$), 60° ($p = 0.003$), 90° ($p = 0.007$) and 180° ($p = 0.045$) on the right side. Furthermore, a significant variance was observed at 60° ($p < 0.001$) and 90° ($p = 0.043$) on the right side in the external rotation angle. While in the upper horizontal distance and upward rotation angle, there were no significant variances between groups (Table 3).

Table 2 Comparison of all outcome variables in shoulder flexion between scapulocostal syndrome patients (SCS) and healthy group (n = 78; SCS = 39, healthy = 39).

	Sides	Lower horizontal distance (mm)			Upper horizontal distance (mm)			Upward rotation angle (degrees)			Superior translation angle (degrees)			External rotation angle (degrees)		
		SCS	Healthy	*p*-value	SCS	Healthy	*p*-value	SCS	Healthy	*p*-value	SCS	Healthy	*p*-value	SCS	Healthy	*p*-value
0	Lt.	78.13 (11.86)	76.12 (11.87)	0.458	71.94 (11.39)	72.85 (12.06)	0.733	95.00 (5.83)	94.40 (7.23)	0.685	69.16 (2.94)	69.85 (3.39)	0.342	3.60 (2.51)	3.84 (2.35)	0.673
	Rt.	77.95 (16.69)	83.24 (12.59)	0.118	74.51 (12.72)	76.49 (10.11)	0.448	98.55 (7.87)	97.42 (6.59)	0.490	68.76 (3.65)	70.34 (4.00)	0.073	4.02 (2.54)	4.21 (2.72)	0.759
30	Lt.	89.32 (12.88)	89.65 (12.92)	0.910	79.18 (12.70)	80.27 (12.03)	0.697	104.64 (10.60)	106.71 (9.24)	0.360	69.98 (3.83)	70.84 (4.36)	0.361	5.37 (3.87)	6.49 (4.37)	0.234
	Rt.	90.73 (15.90)	98.63 (15.52)	0.029*	82.19 (12.77)	86.23 (12.74)	0.166	108.76 (10.20)	110.13 (9.14)	0.535	70.30 (3.64)	72.51 (4.44)	0.019*	5.35 (3.35)	7.32 (4.22)	0.026*
60	Lt.	103.52 (14.64)	101.25 (12.78)	0.467	85.93 (10.52)	86.78 (10.68)	0.722	116.22 (11.87)	118.23 (7.97)	0.383	72.69 (4.45)	73.91 (4.45)	0.230	11.36 (5.82)	10.64 (5.89)	0.585
	Rt.	101.44 (14.32)	110.12 (11.79)	0.005*	87.88 (14.38)	92.01 (11.65)	0.168	119.77 (11.79)	121.50 (9.34)	0.475	72.85 (4.59)	75.54 (4.16)	0.008*	9.11 (5.33)	12.71 (6.55)	0.009*
90	Lt.	110.56 (10.75)	111.02 (13.55)	0.870	89.78 (9.86)	88.10 (12.81)	0.518	130.81 (10.40)	132.42 (7.28)	0.432	76.74 (3.78)	78.59 (5.05)	0.072	18.02 (9.20)	19.41 (8.75)	0.498
	Rt.	112.79 (12.65)	121.10 (12.70)	0.005*	92.17 (12.37)	93.44 (11.49)	0.638	133.72 (9.18)	133.28 (9.89)	0.838	77.03 (4.10)	80.02 (4.55)	0.003*	17.68 (7.20)	21.95 (5.85)	0.005*
120	Lt.	114.17 (10.75)	113.54 (13.17)	0.819	84.11 (9.26)	80.79 (13.00)	0.197	141.11 (8.43)	140.89 (9.98)	0.915	82.86 (6.14)	82.96 (6.10)	0.948	25.74 (9.10)	28.25 (9.97)	0.250
	Rt.	117.45 (11.84)	124.85 (11.33)	0.006*	87.25 (12.67)	87.78 (11.53)	0.847	143.39 (8.48)	143.02 (9.94)	0.861	81.89 (5.73)	84.55 (5.53)	0.041*	26.37 (8.36)	30.96 (7.38)	0.012*
150	Lt.	115.39 (9.99)	113.10 (11.44)	0.348	79.41 (9.39)	77.10 (12.97)	0.369	144.94 (9.79)	147.95 (6.86)	0.120	84.45 (5.97)	82.60 (5.99)	0.176	33.45 (6.98)	32.83 (9.02)	0.738
	Rt.	117.95 (11.57)	124.39 (10.95)	0.014*	80.33 (11.80)	83.84 (11.95)	0.197	143.82 (8.60)	147.20 (5.82)	0.046*	83.28 (6.36)	84.72 (4.55)	0.255	35.03 (7.85)	35.84 (7.10)	0.633
180	Lt.	115.67 (10.90)	117.73 (13.37)	0.459	72.95 (10.86)	71.97 (12.24)	0.709	148.12 (9.43)	150.95 (9.55)	0.192	81.56 (6.45)	80.86 (4.87)	0.591	42.32 (6.61)	40.32 (6.25)	0.174
	Rt.	119.26 (13.55)	125.53 (12.02)	0.034*	73.19 (10.85)	76.92 (13.77)	0.188	147.71 (8.87)	152.29 (8.78)	0.025*	80.26 (5.99)	83.55 (6.97)	0.029*	43.76 (5.82)	43.69 (6.30)	0.960

Data presented as mean (SD); * Statistically significant difference between groups ($p < 0.05$) by independent sample t-test; mm: millimeter.

Table 3 Comparison of all outcome variables in shoulder abduction between scapulocostal syndrome patients (SCS) and healthy group (n = 78; SCS = 39, healthy = 39).

	Sides	Lower horizontal distance (mm)			Upper horizontal distance (mm)			Upward rotation angle (degrees)			Superior translation angle (degrees)			External rotation angle (degrees)		
		SCS	Healthy	*p*-value	SCS	Healthy	*p*-value	SCS	Healthy	*p*-value	SCS	Healthy	*p*-value	SCS	Healthy	*p*-value
0	Lt.	78.13 (11.86)	76.44 (11.82)	0.530	71.94 (11.39)	73.30 (12.06)	0.610	95.22 (6.20)	94.36 (7.68)	0.590	69.13 (2.99)	69.33 (3.52)	0.785	3.74 (2.46)	3.96 (2.55)	0.699
	Rt.	77.95 (16.69)	83.22 (11.83)	0.112	75.27 (11.70)	77.63 (10.92)	0.360	98.55 (7.87)	97.98 (6.60)	0.729	68.61 (3.63)	70.23 (3.93)	0.061	4.25 (2.82)	4.10 (2.87)	0.815
30	Lt.	80.68 (15.12)	76.81 (17.90)	0.306	63.45 (10.87)	64.14 (14.71)	0.815	101.14 (8.69)	100.20 (9.17)	0.645	71.38 (2.98)	71.49 (3.78)	0.893	7.07 (3.67)	6.11 (3.16)	0.218
	Rt.	78.67 (16.95)	83.54 (13.49)	0.164	65.72 (13.45)	70.02 (14.37)	0.177	103.76 (8.46)	102.94 (8.31)	0.666	70.81 (3.33)	72.88 (4.21)	0.018*	5.51 (2.78)	6.69 (4.44)	0.165
60	Lt.	90.61 (17.38)	90.92 (13.76)	0.930	57.08 (10.86)	52.55 (11.90)	0.083	114.05 (8.66)	111.61 (9.39)	0.235	75.34 (3.50)	75.80 (4.29)	0.608	15.13 (7.61)	16.26 (8.36)	0.534
	Rt.	82.43 (14.27)	93.38 (14.96)	0.001*	60.87 (11.70)	62.06 (12.18)	0.662	117.03 (9.56)	115.52 (8.98)	0.473	75.19 (3.42)	77.80 (4.17)	0.003*	14.09 (6.92)	20.04 (7.30)	0.000*
90	Lt.	104.02 (17.28)	108.29 (16.91)	0.273	60.57 (10.74)	56.48 (10.70)	0.096	128.22 (8.66)	126.22 (8.58)	0.308	78.85 (4.25)	78.83 (4.55)	0.986	30.38 (6.35)	29.12 (6.14)	0.378
	Rt.	98.98 (16.15)	107.44 (14.87)	0.019*	62.65 (13.27)	61.87 (13.75)	0.800	130.36 (8.73)	129.26 (8.99)	0.585	78.45 (4.42)	80.90 (3.29)	0.007*	26.63 (8.53)	30.12 (6.28)	0.043*
120	Lt.	116.69 (15.59)	120.23 (14.81)	0.307	65.64 (8.87)	63.23 (12.24)	0.323	140.30 (7.61)	138.11 (7.55)	0.206	80.91 (5.48)	79.88 (5.53)	0.380	38.23 (4.63)	36.10 (5.48)	0.067
	Rt.	110.00 (11.93)	116.00 (9.84)	0.018*	68.47 (13.26)	71.63 (14.41)	0.318	143.28 (8.22)	140.79 (9.18)	0.211	80.89 (5.48)	81.68 (4.44)	0.488	36.69 (6.04)	37.02 (5.57)	0.805
150	Lt.	117.76 (11.76)	116.41 (12.57)	0.625	69.21 (9.60)	67.91 (11.66)	0.593	147.40 (8.83)	143.62 (8.34)	0.055	82.42 (5.69)	80.52 (6.78)	0.185	41.37 (4.40)	39.33 (6.16)	0.097
	Rt.	119.69 (12.44)	124.44 (12.34)	0.095	70.26 (11.46)	74.14 (12.55)	0.158	148.38 (7.16)	145.14 (9.29)	0.089	81.29 (5.72)	82.36 (5.81)	0.414	41.66 (5.60)	42.22 (5.68)	0.662
180	Lt.	115.82 (11.33)	118.17 (14.06)	0.418	72.73 (11.00)	71.74 (11.21)	0.695	151.80 (8.75)	148.09 (7.89)	0.053	81.38 (6.22)	80.92 (4.94)	0.721	42.48 (6.51)	40.89 (6.52)	0.284
	Rt.	119.57 (13.34)	125.57 (12.86)	0.046*	73.28 (10.80)	75.92 (12.58)	0.324	150.69 (9.42)	148.17 (7.69)	0.200	80.31 (6.08)	83.22 (6.54)	0.045*	43.91 (5.83)	44.55 (5.22)	0.611

Data presented as mean (SD); * Statistically significant difference between groups ($p < 0.05$) by independent sample t-test; mm: millimeter.

4. Discussion

In the current study, the results showed differences in scapular alignment in some outcomes between groups. On comparing shoulder flexion position between groups, lower horizontal distance, upward rotation angle, superior translation angle, and external rotation angle were significantly lower in the SCS group than in the healthy group on the right side. On comparing shoulder abduction position between groups, the lower horizontal distance, superior translation angle, and external rotation angle were pointedly lower in the SCS group than in the healthy group on the right side.

The findings presented a difference only at the right shoulder which was the most dominant shoulder among participants. According to the affected sides in this study, participants with MTrPs at the right shoulder represented 77% of total individuals with SCS. A previous study explored excessive use activating early fatigue due to muscle activation alteration and scapulothoracic dysfunction [23]. Another evidence suggested that the dominant extremity is most often exposed in scapular malalignment. This is likely due to overuse, muscle asymmetry, and difference in range of motion [24].

According to major signs of SCS, MTrPs of the levator scapulae, upper trapezius, serratus anterior, and rhomboid were found in participants with SCS, respectively. From previous studies, MTrPs can be a cause of both muscle weakness and muscle tightness. Periscapular muscle imbalance can be a common cause of scapular malalignment. In muscle weakness, the taut band of the muscle reduces the threshold stimulation which also leads to excessive use, early fatigue, and eventual weakness. MTrPs is a neuroflexive factor for increased muscle tension in which the area of hypertonicity in the affected muscles can generate muscle tightness [7,25]. Both situations are the main reasons for describing the findings of this study.

According to the comparing of shoulder flexion position between groups, the results showed that the lower horizontal distance was significantly lower in the SCS group than in the healthy group during shoulder flexion performed at 30°, 60°, 90°, 120°, 150°, and 180° on the right side. The results also demonstrated that the SCS group displayed a lower upward rotation angle at 150° and 180° on the right side than the healthy group. In addition, the superior translation angle was significantly lower in the SCS group than in the healthy group during shoulder flexion performed at 30°,60°,90°, 120°, and 180°. The external rotation angle was significantly lower in the SCS group than in the healthy group during shoulder flexion performed at 30°, 60°, 90°, and 120° on the right side. The lower horizontal distance is the distance between the inferior angle of the scapula and the spinous process. If the outcome shows decreased distance, the inferior angle is close to the midline. This change may be due to the signs of muscle imbalance according to Janda's concept. Muscle imbalance in the upper body is one scenario related to these results. It demonstrates tightness in the pectoral and neck extensor muscles, whereas weakness of the neck flexor and interscapular muscles may occur simultaneously [7]. Muscle imbalance can alter scapular alignment, especially in interscapular muscle weakness. During shoulder flexion or abduction, the serratus anterior muscles must produce a large upward rotation torque to the scapula. The force-couple formed by the serratus anterior and upper and lower trapezius is initiated for this torque [26]. In these interscapular muscles weaknesses, the unrestricted strong pull of the glenohumeral abductors can cause the scapular to paradoxically downwardly rotate during active shoulder abduction [27]. In the upward rotation angle alterations, Bostad and Ludewig reported that the scapular downward rotated position presented slight scapular internal rotation in individuals with short pectoralis minor muscle length without shoulder pain [28]. Moreover, the combination between serratus anterior weakness and pectoralis minor tightness may be related to abnormal alignment of the cervicothoracic region [10,29]. Nonetheless, the upward rotation angle showed a significant difference only during shoulder flexion. Based on the MTrPs in SCS patients in the study, this sign of the scapular muscles can limit the scapular motion, especially the serratus anterior [7]. Ekstrom et al investigated the surface EMG activity in serratus anterior during exercises. When a diagonal exercise with a combination of shoulder flexion was performed, the serratus anterior was activated maximally with exercises requiring a great amount of scapular upward rotation. Likewise, the shoulder abduction in the plane of the scapula above 120° also produced far greater EMG activity in the serratus anterior [30]. Henceforth, shoulder flexion was performed through forward shoulder flexion, which is similar to a diagonal exercise with a combination of shoulder flexion. The MTrPs of the serratus anterior in SCS patients was 23%, which implied the reasons for the only difference in shoulder flexion. The superior translation and the external rotation angle may be reduced by the excessive anterior tilt and internal rotation of the scapula. This situation may appear due to shortening of the pectoralis minor and weakness of the interscapular muscles [28]. In a study by Harrison and colleagues, the increased scapular internal rotation and decreased scapular posterior tilting at greater arm elevation angles can occur due to serratus anterior weakness [31].

With regard to the comparison of shoulder abduction position between groups, the findings represented that lower horizontal distance was significantly lower in the SCS group than in the healthy group during shoulder abduction performed at 60°, 90°, 120°, and 180° on the right side. What's more, the superior translation angle was pointedly lower in the SCS group than in the healthy group during shoulder abduction at 30°, 60°, 90°, and 180° on the right side. On the other hand, the external rotation angle was significantly lower in the SCS group than in the healthy group during shoulder abduction at 60°and 90° on the right side. According to normal lower horizontal distance, the distance tended to indicate distance values from the midline when the degree of shoulder abduction was increased. The lower values in the SCS group than in the healthy group may be due to the MTrPs - especially in the rhomboid muscles. The taut band of the muscles causes a movement pattern alteration or altered joint positioning resulting from changed tension [7]. On the other hand, the MTrPs in the serratus anterior may promote the low distance discovered in the SCS group in terms of muscle weakness. Muscles with MTrPs fatigue more rapidly than those without MTrPs. The poor synchronization and decreased number of firing motor units can occur in the muscles with MTrPs [7,32]. In the superior translation angle and the external rotation angle, the shortening of the pectoralis minor may have presented adaptations such as induced proportions of connective tissue and loss of sarcomeres in series. According to these adaptations, the increased tension of the muscles during arm elevation may limit scapulothoracic joint motion and range of motion, especially in both outcomes [33]. However, the pectoralis minor length was not investigated in this study. The possible reasons are predicted due to the nature of SCS.

According to the different findings of degrees between during shoulder flexion and abduction, the possible reasons for these situations are described. In the lower horizontal distance, the SCS group did not demonstrate a significant difference at 30° and 150° of shoulder abduction. With regard to the superior translation angle, the SCS group presented no significant difference at 120° of shoulder abduction. In the external rotation angle, the SCS group demonstrated no significant difference at 30°and 120° of shoulder abduction. The reasons may involve the setting phase in which the scapula contributes slightly to the totally elevated shoulder. Although a consensus on duration of the setting phase has not been defined, several researchers agreed that during shoulder elevation, the majority of the scapular upward rotation, scapular external rotation, and scapular posterior tilting occur after 90° of humeral elevation [34-36]. These reports refer to the possible causes of the non-significant difference at low degrees of shoulder abduction, i.e., 30° in the lower horizontal distance and the external rotation angle. Escamilla et al reported the maximum voluntary isometric contraction (MVIC) of scapular muscles via EMG investigation during shoulder exercises. Hence, shoulder abduction above 120° with external rotation represented %MVIC greater than 50% in the upper trapezius, lower trapezius, rhomboids, and serratus anterior, while shoulder flexion above 120° with external rotation showed %MVIC greater than 50% in the lower trapezius and serratus anterior [37]. The synergistic scapular muscles contribute a large amount in shoulder abduction which leads to scapular alignment stabilization. Thus, the co-contraction of these muscles may be the cause of the non-alterations of scapular alignment at above 120° of shoulder abduction, such as 150° in the lower horizontal distance, 120° in the superior translation angle, and 120° in the external rotation angle. Although the results revealed varying findings of degrees between during shoulder flexion and abduction, some results also showed the trends of scapular alignment alteration with *p*-value ranged between 0.095 to 0.164 in the lower horizontal distance of shoulder abduction.

This study has some limitations. First, it did not evaluate muscle power and muscle length for the elucidation of results. A follow-up study should add these parameters to clarify outcomes and reasons. Second, the five outcomes of this study detected problems concerning the coronal and transverse planes of scapula movement. Movements on the sagittal plane or scapular anterior/posterior tilting were predicted via outcomes of superior translation angle. Third, this study only reported trends of scapular position alteration due to no cut-off point for scapular dyskinesis diagnosis. What's more, cut-off values in the outcomes to confirm the relationship between SCS and scapular dyskinesis ought to be investigated.

5. Conclusion

This study explored the variances in scapular alignment between individuals with SCS and healthy participants. Lower horizontal distance, upward rotation angle, superior translation angle, and external rotation angle in SCS patients were lower than in healthy participants at the right shoulder. This situation may be related to scapular malalignment in scapular downward rotation, anterior tilting, and internal rotation positions which tended to indicate scapular dyskinesis. Finally, physical therapists or health professionals ought to emphasize scapular alignment investigation and treatment among SCS patients.

6. Ethical approval

The study was approved by the Center for Ethics in Human Research, Khon Kaen University (HE631415).

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8. References

[1] Abrams B. Scapulocostal syndrome. In: Waldman SD, editor. Pain management, vol. 2. Philadelphia: Saunders; 2011. p. 588-592.

[2] Cohen CA. Scapulocostal syndrome: diagnosis and treatment. South Med J. 1980;73(4):433-437.

[3] Waldman SD. Atlas of common pain syndromes. 3rd ed. Philadelphia: Saunders; 2012.

[4] Schmerl M. Clinical update: Scapulo-costal syndrome. Australas Chiropr Osteopathy. 2002;10(2):85-86.

[5] Fourie LJ. The scapulocostal syndrome. S Afr Med J. 1991;79:721-724.

[6] Kibler WB. The role of the scapula in athletic shoulder function. Am J Sports Med. 1998;26(2):325-337.

[7] Page P, Frank C, Larder R. Assessment and treatment of muscle imbalance: the Janda approach. 1st ed. Illinois: Human kinetics; 2010.

[8] Cailliet R. Shoulder Pain (Pain Series). 3rd ed. Philadelphia: F.A. Davis Co; 1991.

[9] Capuano A, Currò D, Dello Russo C, Tringali G, Pozzoli G, Trapani Di G, et al. Nociceptin (1-13) NH2 inhibits stimulated calcitoningene-related-peptide release from primary cultures of rat trigeminal ganglia neurones. Cephalalgia. 2007;27(8):868-876.

[10] Kibler WB, Sciascia A, Wilkes T. Scapular dyskinesis and its relation to shoulder injury. J Am Acad Orthop Surg. 2012;20(6):364-372.

[11] Kibler WB, Ludewig PM, McClure PW, Michener LA, Bak K, Sciascia AD. Clinical implications of scapular dyskinesis in shoulder injury: the 2013 consensus statement from the 'Scapular summit'. Br J Sports Med. 2013;47(14):877-885.

[12] Sahrmann, SA. Diagnosis and treatment of movement impairment syndromes 1st ed. St. Louis: MO: Mosby; 2002.

[13] Ha SM, Kwon OY, Yi CH, Cynn HS, Weon JH, Kim TH. Effects of scapular upward rotation exercises on alignment of scapula and clavicle and strength of scapular upward rotators in subjects with scapular downward rotation syndrome. J Electromyogr Kinesiol. 2016;26:130-136.

[14] Cools AM, Witvrouw EE, Declercq GA, Vanderstraeten GG, Cambier DC. Evaluation of isokinetic force production and associated muscle activity in the scapular rotators during a protraction-retraction movement in overhead athletes with impingement symptoms. Br J Sports Med. 2004;38(1):64-68.

[15] Cools AM, Declercq GA, Cambier DC, Mahieu NN, Witvrouw EE. Trapezius activity and intramuscular balance during isokinetic exercise in overhead athletes with impingement symptoms. Scand J Med Sci Sports 2007;17(1):25-33.

[16] Burn MB, McCulloch PC, Lintner DM, Liberman SR, Harris JD. Prevalence of scapular dyskinesis in overhead and nonoverhead athletes: a systematic review. Orthop J Sports Med. 2016;4(2):2325967115627608.

[17] Ozdemir F, Toy S. Evaluation of scapular dyskinesis and ergonomic risk level in office workers. Int J Occup Saf Ergon. 2021;27(4):1193-1198.

[18] Akodu AK, Akinbo SR, Young QO. Correlation among smartphone addiction, craniovertebral angle, scapular dyskinesis, and selected anthropometric variables in physiotherapy undergraduates. J Taibah Univ Med Sci. 2018;13(6):528-534.

[19] Sanchez HM, Sanchez EG, Tavares LI. Association between scapular dyskinesia and shoulder pain in young adults. Acta Ortop Bras. 2016;24(5):243-248.

[20] Park JY, Hwang JT. Scapular dyskinesis: part II. A new diagnostic modality-three-dimensional wing CT. In: PARK JY, editors. Sports injuries to the shoulder and elbow. Berlin: Springer; 2015. p. 157-166.

[21] Larsen CM, Søgaard K, Eshoj H, Ingwersen K, Kristensen JB. Clinical assessment methods for scapular positioning and function. An inter-rater reliability study. Physiother Theory Pract. 2019;29:1-22.

[22] D'hondt NE, Pool JM, Kiers H, Terwee CB, Veeger DH. Validity of clinical measurement instruments assessing scapular Function: insufficient evidence to recommend any instrument for assessing scapular posture, movement, and dysfunction-a systematic review. J Orthop Sports Phys Ther. 2020;50(11):632-641.

[23] Pimentel LSR, Paiva MC, Fagundes DJ. Prevalência de dores no ombro de jogadores universitários de handebol. Rev Bras Quiro. 2011;2(1):112-117.

[24] Jildeh TR, Ference DA, Abbas MJ, Jiang EX, Okoroha KR. Scapulothoracic dyskinesis: a concept review. Curr Rev Musculoskelet Med. 2021;14(3):246-254.

[25] Simons DG, Travell JG, Simons LS. Myofascial pain and disfunction. The trigger point manual. 2nd ed. Baltimore: Williams & Wilkins; 1999.

[26] Camci E, Duzgun I, Hayran M, Baltaci G, Karaduman A. Scapular kinematics during shoulder elevation performed with and without elastic resistance in men without shoulder pathologies. J Orthop Sports Phys Ther. 2013;43(10):735-743.

[27] Neumann DA, Camargo PR. Kinesiologic considerations for targeting activation of scapulothoracic muscles - part 1: serratus anterior. Braz J Phys Ther. 2019;23(6):459-466.

[28] Borstad JD, Ludewig PM. The effect of long versus short pectoralis minor resting length on scapular kinematics in healthy individuals. J Orthop Sports Phys Ther. 2005;35(4):227-238.

[29] Helgadottir H, Kristjansson E, Einarsson E, Karduna A, Jonsson H. Altered activity of the serratus anterior during unilateral elevation in patients with cervical disorders. J Electromyogr Kinesiol. 2011;21:947-953.

[30] Ekstrom RA, Donatelli RA, Soderberg GL. Surface electromyographic analysis of exercises for the trapezius and serratus anterior muscles. J Orthop Sports Phys Ther. 2003;33(5):247-258.

[31] Harrison N, Garrett WZ, Timmons MK. Serratus Anterior Fatigue Reduces Scapular Posterior Tilt and External Rotation During Arm Elevation. J Sport Rehabil. 2021;30(8):1151-1157.

[32] Janda V. Muscle strength in relation to muscle length, pain, and muscle imbalance. In: Ringdahl KH, editors. Muscle strength. Edinburgh: Churchill Livingstone; 1993. p. 83-91.

[33] Tabary JC, Tardieu C, Tardieu G, Tabary C. Experimental rapid sarcomere loss with concomitant hypoextensibility. Muscle Nerve. 1981;4(3):198-203.

[34] McClure PW, Michener LA, Sennett BJ, Karduna AR. Direct 3-dimensional measurement of scapular kinematics during dynamic movements in vivo. J Shoulder Elbow Surg. 2001;10(3):269-277.

[35] Ludewig PM, Phadke V, Braman JP, Hassett DR, Cieminski CJ, LaPrade RF. Motion of the shoulder complex during multiplanar humeral elevation. J Bone Joint Surg Am. 2009;91(2):378-389.

[36] Fung M, Kato S, Barrance PJ, Elias JJ, McFarland EG, Nobuhara K, Chao EY. Scapular and clavicular kinematics during humeral elevation: a study with cadavers. J Shoulder Elbow Surg 2001;10(3):278-285.

[37] Escamilla RF, Yamashiro K, Paulos L, Andrews JR. Shoulder muscle activity and function in common shoulder rehabilitation exercises. Sports Med. 2009;39(8):663-685.