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Original Article

Comparison of scapulothoracic muscles onset and deactivation time between individuals with and without inferior angle type of scapular dyskinesis: A cross-sectional study

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Abstract

This is a cross-sectional study that aimed to compare upper trapezius (UT), middle trapezius (MT), lower trapezius (LT), and serratus anterior (SA) muscle onset, deactivation, and activation time from surface electromyography (sEMG) in shoulder flexion, scaption, and abduction between the inferior angle type of scapular dyskinesis (ISD) group (n = 6) and normal pattern of scapular motion (NP) group (n = 6). An independent t-test was used for statistical analysis. In flexion, early MT and LT deactivation time were found, and MT activation time in the ISD was shorter than the NP ($p < 0.05$). In scaption, early LT, and SA deactivation time were found in the ISD ($p < 0.05$). In abduction, UT deactivation and activation time were significantly different between groups ($p < 0.05$). This study demonstrated the early time of muscle deactivation and shorter muscle activation time of the scapular force couple muscles. Therefore, the active scapular control should be emphasized during shoulder elevation.

Keywords: scapula, electromyography, muscles, pain, onset

1. Introduction

These days, hours of computer use have been increasing in educational and working environments. Office workers use computers for at least four hours a day, and 90% of them use computers daily (Gerr, Marcus, & Monteilh, 2004; Tittiranonda, Rempel, Armstrong, & Burastero, 1999). Therefore, the high incidence of the musculoskeletal complaints regarding the neck and shoulder is common among office workers (Gerr *et al.*, 2004). Previous studies found that there was an alteration of the control of muscle in cervical in people with neck pain (Falla, Bilenkij, & Jull, 2004). Furthermore, there is an evidence that the disturbing scapula function could occur in people with neck pain (Cagnie *et al.*, 2014; Cools *et al.*, 2014) and could change the stability of the scapula which affect the recurrence of neck pain (Sahrmann, 2011).

The scapula, as a link between the shoulder and the cervical spine, provide the stability while neck and shoulder are moving and it is dependent upon the surrounding muscle around the scapula (Paine & Voight, 1993). Three segments of serratus anterior muscle hold the medial side of the scapula to the chest wall and counteract scapular internal rotation caused by the weight of the arm in front of the body. Also, when combining with the upper and lower trapezius, the muscles are analogous to three arms rotating the scapula upwards (Crowe & Elhassan, 2016). The force couple of the scapula consists of the scapula upward rotation force by upper and lower trapezius muscles result in the adduction force of the scapula that counterbalance by the abduction force of the serratus

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anterior muscle (Crowe & Elhassan, 2016; Sahrmann, 2002). These muscles allow the scapula to be symmetrical at rest and during movement. If there are any observable alterations in the position of the scapula and the patterns of scapular motion in relation to the thoracic cage, scapular dyskinesis is considered (Kibler, Sciascia, & Wilkes, 2012). According to Kibler et al (Kibler *et al.*, 2002), scapular dyskinesis can be classified into four types. Type I, inferior angle type, is characterized by prominence of the inferomedial scapular angle and would be associated with excessive anterior tilting of the scapula. Type II, medial border type, is characterized by prominence of the entire medial border and would be associated with excessive scapular internal rotation. Type III, superior border type, is characterized by prominence of the superior scapular border and would be associated with excessive upward translation of the scapula. Type IV, symmetric scapulohumeral type, is considered a normal type in which no asymmetries are identified and no prominence of the medial or superior border is observed. This classification of scapula reported the intra- and inter-rater reliability of fair to moderate (Huang, Huang, Wang, Tsai, & Lin, 2015; Kibler *et al.*, 2002). The shorter pectoralis minor and upper trapezius length were found in observable scapular dyskinesis (Yeşilyaprak, Yüksel, & Kalkan, 2016), which could possibly cause the increase in scapular internal rotation and anterior tilting which found in the inferior angle type of scapular dyskinesis (Tyler, Nicholas, Roy, & Gleim, 2000; Vermeulen *et al.*, 2002). There is limited evidence in inferior type of scapular dyskinesis and shoulder pain. However, the presence of the anterior tilting and internal rotation of the scapula could decrease subacromial space and increase the compression of rotator cuff muscles and the symptoms of the shoulder impingement syndrome (Kibler, Sciascia, & Dome, 2006). Furthermore, in patients with shoulder pain found the decrease of the serratus anterior muscle activation and strength that could cause the loss of posterior tilt and upward rotation (Cools *et al.*, 2007) and could result in the decrease of the ability of the scapular stabilization by holding medial scapula to the chest wall and the increase of anterior tilting of the scapula (Ludewig & Cook, 2000) which are the characteristics of the inferior angle type of the scapular dyskinesis. Therefore, this study focused on the inferior angle type of scapular dyskinesis. Moreover, the alterations of motor control around scapula could be investigated by the muscle onset and the deactivation time by using the electromyography (Zhou & Zhang, 2014). The muscle onset time could be considered as the time at the muscle activity reached the target threshold. The time at the muscle activity failed to reach the particular threshold is considered as muscle deactivation time which can be processed in many approaches. In the study of muscle onset time, identified as the time at the muscle activity reached the five percent of maximum amplitude, revealed the normal scapular muscle recruitment order as upper trapezius activation followed by serratus anterior muscle, and the lower trapezius muscle (Wadsworth & Bullock-Saxton, 1997). However, the alterations of the motor control in people with pain could change the activation of the muscle. In the study of muscle onset time, it was found that people with idiopathic neck pain had a delayed onset of muscle timing and shorter duration of the serratus anterior muscle activation during unilateral elevation when compared with an asymptomatic group (Helgadottir, Kristjansson, Einarsson, Karduna, & Jonsson, 2011). Moreover, people with impingement showed the differences strategies in motor control of the serratus anterior by early deactivation time which identified as the time at the mean of moving window was lower or equal to the sum of mean baseline activity plus three standard deviations and early contraction of upper trapezius muscle (Phadke & Ludewig, 2013). As well as the inferior type of scapular dyskinesis that could alter the control of the muscles around scapula because a normal movement of scapula requires the optimal neuromuscular strategies of the muscles contraction to stabilize the scapular anterior tilt during shoulder elevation (Struyf *et al.*, 2014). Therefore, the different possible muscle activation patterns are hypothesized to be found following the scapular dyskinesis. This information could lead to a better understanding and effectiveness in rehabilitation for individuals who have upper quadrant complaints. However, there is limited evidence of muscle onset time, muscle deactivation time, and muscle activation time of office workers with inferior angle type scapular dyskinesis. The aim of this study was to compare muscle onset time, muscle deactivation time, and muscle activation time in individuals with and without inferior angle type scapular dyskinesis.

2. Materials and Methods

2.1 Study design

The present study was a cross-sectional study. The laboratory setting was at the physical therapy department, Mahidol University. This study was approved by Mahidol University Central Institutional Review Board (MU-CIRB 2017/233.1912) based on the Declaration of Helsinki. Informed consent was signed prior to participation.

2.2 Participants

There were many previous studies that found the delayed onset, shorter activation duration and also the early deactivation time of SA, however, there was the evidence that also showed the alteration in the control of LT muscle which could happen in inferior angle type of scapular dyskinesis (Helgadottir *et al.*, 2011; Phadke & Ludewig, 2013). In the presence of inferior angle type of scapular dyskinesis, the possible different muscle activation pattern was hypothesized by having the delay of the muscle onset time and early muscle deactivation time in LT and SA. In addition to that, the sample size was estimated using a formula of two independent means (two-tailed test) on the basis of the previous study of muscle onset in LT during unilateral arm elevation which was selected from insidious onset neck pain group and the control group that showed the delay onset of LT in insidious onset neck pain group when compared to control group (Helgadottir *et al.*, 2011) assuming 5% significance, 80% power and 20% drop out. The participants were 6 per group. The total sample size was 12 participants. Six individuals with upper quadrant complaints with inferior scapular dyskinesis and six with normal patterns of scapular motion voluntarily participated in this study. All participants were recruited from Mahidol University, Bangkok, Thailand, from March to August 2018. Participants were included if they were aged 18–55 years with body mass indices (BMI) < 25 kg/m^2. In inferior angle type of scapular dyskinesis (ISD) group, they underwent scapular dyskinesis testing and were identified as having scapular dyskinesis with inferior angle type and were using a computer at least four hours continuously each day for at least one year with the presence of neck, shoulder, or scapular symptoms defined as uncomfortable feeling or pain at rest in the areas between the inferior margin of the occiput and seventh thoracic vertebrae (T7), excluding the area below the glenohumeral (GH) joint, within seven days and for at least three months in one year, using numeric rating scale $\geq 3/10$, with the presence of scapular dyskinesis in inferior angle type, and a score on the neck disability index (Thai version) of at least 5/50. In normal pattern of scapular motion (NP) group, they underwent scapular dyskinesis testing and were identified as having normal scapular pattern with no upper quadrant complaints. Participants were excluded if they had 1) a history of neck, shoulder, or scapular fracture or surgery, 2) trauma of the upper quadrant within six months, 3) diagnosis of fibromyalgia 4) diagnosis of cervical radiculopathy (tested with cervical compression test, cervical distraction test) or shoulder pathology (tested with-The Hawkins-Kennedy test and the painful arc test), 5) systemic disease or other soft tissue disorders (for example, gout, rheumatoid, systemic lupus erythematosus), 6) obvious scoliosis (tested with Adam's forward bending test), 7) central nervous system disorders such as stroke, brain injury, 8) congenital thoracic deformities, 9) thoracic kyphosis more than 45º, and 10) participated in an intensive exercise program, physical therapy program, or been taking traditional Thai or Chinese medicine for neck and shoulder pain within six weeks or receiving analgesic, anti-inflammatory, or muscle relaxant drugs within seven days. The side of a surface electromyography (sEMG) attachment in the NP group was selected to match the side of pain in the ISD group.

2.3 Procedures

The scapular dyskinesis identification was done by a physical therapist with more than five years of experience in treating patients with musculoskeletal conditions. This study did not provide kinematic data of the scapular dyskinesis. Therefore, the assessor went through the training protocol for the validity of the assessor, who identified the scapular dyskinesis in this study, which consisted of didactics, hands-on training and verification training prior to the beginning of data collection. For didactic periods, the physical therapist reviewed the normal and abnormal anatomy and biomechanics of the scapula and the concept of scapular dyskinesis including evaluation and classifications. For hands-on practice periods, the physical therapist practiced classification of scapular dyskinesis using visual observation and a scapular dyskinesis test method. This session ended when the physical therapist was able to perform the entire examination. This period had three hands-on practice sessions. During verification periods, the physical therapist was re-evaluated by an expert instructor. The physical therapist and expert evaluated five participants with neck, shoulder, and scapular complaints. If the physical therapist was able to evaluate and correctly classify at least four out of five, the expert instructor accepted the performance of the assessor and passed on to the testing sessions.

For scapular dyskinesis identification, participants performed five repetitions of active bilateral shoulder flexion, scaption and abduction without weight for three seconds per phase and a total of six seconds for one cycle and then repeated the shoulder flexion, scaption and abduction by holding dumbbells of 1.4 kilograms for the participants who had body weights less than 68.1 kilograms and 2.3 kilograms for those of more than 68.1 kilograms (Huang *et al.*, 2015; McClure, Tate, Kareha, Irwin, & Zlupko, 2009; Uhl, Kibler, Gecewich, & Tripp, 2009). After that, the subjects were seated and received skin preparation by cleaning the electrode placement area.

A surface electromyography (sEMG) (Naroxon Inc., USA) was used to determine the muscle onset time, muscle deactivation time, and muscle activation time. The electrodes were placed at UT, MT, LT, and SA. SA electrodes were attached to the anterior border of the latissimus dorsi at rib levels 6–8. UT electrodes were attached to the midpoint of the acromion and the spinous process of C7. MT electrodes were attached to the line between the medial border of the scapula and the spine at the level of T3 in the direction of the line between T5 and the acromion. LT electrodes were attached at 2/3 on the line from the trigonum spinae to the T8 in the direction of the line between T8 and the acromion (Hermens, Freriks, Disselhorst-Klug, & Rau, 2000). The electrodes were triode surface and had 20 mm of inter-electrode distance. After that, the participant performed the shoulder scaption. The metronome was set at 60 beats per minute. The subjects became familiar with the testing protocol and practiced with the metronome to precisely perform movements at an even pace. Subjects performed three trials, resting for one minute between exercises, the order being randomized for each participant.

2.4 Data analysis

The signal will be amplified with input impedance of 10 Giga Ohm using a common mode rejection ration of 110 dB. The sampling rate was at 1500 Hz, and the data went through a band pass filter with a cut-off frequency of 16 Hz and 482 Hz. Data was then high-pass filtered with cut-off frequency at 30 Hz (Hermens *et al.*, 2000). Muscle onset time was defined as time when muscle activity exceeded two standard deviations above baseline activity for at least 50 milliseconds (Hodges & Bui, 1996). The deactivation time was set as the mean of muscle activity that was lower or equal to two standard deviations above baseline. The muscle activation time was identified as the time of muscle activity maintained in two standard deviations above baseline activity (Helgadottir *et al.*, 2011).

2.5 Statistical analysis

The level of significance was set at $p \leq 0.05$ representing significant difference. All analyses used the IBM SPSS Statistics for Windows, Version 19.0 (Armonk, NY: IBM Corp.). The demographic data were presented in descriptive statistics. A Shapiro-Wilk test was used for normal distribution testing. The data were normally distributed (Table 1) then an independent t-test was used for analyzing the difference between the two groups for the demographic data for BMI, age and the primary outcomes which were muscle onset time, muscle deactivation time, and muscle activation time. The data were presented in mean, standard deviation

Table 1. The results of the normality testing of muscle onset time, muscle deactivation time, and muscle activation time in shoulder flexion, scaption and abduction between ISD group and NP group

Group	ISD (p-value)	NP (p-value)	ISD (p-value)	NP (p-value)	ISD (p-value)	NP (p-value)
Muscle onset time	Flexion		Scaption		Abduction	
UT	0.093	0.418	0.269	0.362	0.666	0.580
MT	0.673	0.698	0.258	0.914	0.059	0.841
LT	0.984	0.343	0.130	0.113	0.911	0.302
SA	0.967	0.052	0.960	0.588	0.884	0.400
Muscle deactivation Time	Flexion		Scaption		Abduction	
UT	0.675	0.187	0.524	0.350	0.420	0.401
MT	0.160	0.900	0.239	0.309	0.836	0.548
LT	0.337	0.853	0.721	0.898	0.812	0.439
SA	0.780	0.956	0.492	0.850	0.806	0.726
Muscle activation duration	Flexion		Scaption		Abduction	
UT	0.280	0.315	0.402	0.777	0.625	0.337
MT	0.519	0.387	0.837	0.769	0.829	0.679
LT	0.775	0.637	0.665	0.920	0.245	0.532
SA	0.586	0.254	0.357	0.448	0.357	0.638

ISD group = inferior angle type of scapular dyskinesis group, NP group = normal pattern of scapula, *significant difference between group ($p < 0.050$)

(SD), mean differences, and 95% confidence interval (95% CI). All parameters from three trials during flexion, scaption, and abduction were averaged.

3. Results and Discussion

The characteristics of the participants showed no significant difference in age and BMI between the ISD group and the NP group. In ISD group, the numeric pain rating scale was 7.33 (1.63), and the neck disability index (Thai version) was 6.67 (1.63) (Table 2).

Table 2. Demographic data for the participants in ISD group and NP group

	ISD group[a] (n = 6)	NP group[a] (n = 6)
Age (years)	37.33 (8.17)	27.67 (7.97)
BMI (kg/m^2)	21.40 (1.95)	23.09 (2.35)
NDI (Thai version) (50)	6.67 (1.63)	0
Numeric pain rating scale (0-10)	7.33 (1.63)	0

In shoulder flexion trials, the muscle onset time was not significantly different between the two groups in any muscles. However, this study found that ISD group had significantly early MT muscle (5.15 (0.37) sec) and LT muscle (4.90 (0.45) sec) deactivation time compared to MT muscle deactivation time (5.66 (0.21) sec), $t (10) = 2.93$; $P = 0.051$ and LT muscle deactivation time (5.58 (0.21) sec), $t (10) = 3.36$; $p = 0.012$) in the NP group. Similarly, there was a significantly shorter muscle activation time of MT (4.46 (0.34) sec) compared to muscle activation time of MT (4.96 (0.24) sec), $t (10) = 2.93$; $p = 0.015$) in the NP group (Table 3).

In shoulder scaption trials, The ISD group had an early LT muscle deactivation time (5.07 (0.40) sec) and SA muscle deactivation time (4.89 (0.18) sec) when compared to LT muscle deactivation time (5.58 (0.25) sec), $t (10) = 2.63$; $p = 0.025$) and SA muscle deactivation time (5.55 (0.28) sec), $t (10) = 4.82$; $p = 0.001$) in NP group. However, there was no significantly different between the two groups in muscle activation time (Table 4).

In shoulder abduction trials, only UT in ISD group showed the early deactivation (5.40 (0.17) sec) and had the shorter muscle activation time (4.77 (0.24) sec) compared to UT muscle deactivation (5.74 (0.23) sec), $t (10) = 2.86$; $p = 0.017$) and muscle activation time (5.17 (0.18) sec), $t (10) = 3.22$; $p = 0.009$) in the NP group (Table 5).

The major finding of this study is the alteration of motor control in inferior angle type of scapular dyskinesis in terms of the early time of muscle deactivation and shorter muscle activation time of LT and SA. This study did not find any difference in muscle onset time between the two groups, contrary to the previous study that found a delayed onset of serratus anterior in an idiopathic neck pain and whiplash-associated disorder group when compared to an asymptomatic group (Helgadottir *et al.*, 2011). However, there were no differences in muscle onset time, and this study demonstrated the alteration of LT and SA muscle deactivation in scaption. This study supports the role of force couple in the scapula. The function of LT is depressing the scapula, assisting upward rotation of the scapula and also providing the posterior tilting and external rotation of the scapula (Johnson, Bogduk, Nowitzke, & House, 1994). As well as the functions of the SA which are to counteract the rotation due to the weight of the arm and to stabilize the scapula by holding the medial scapula to the chest wall and to assist the upward and external rotation of the scapula by pulling on the inferomedial border of the scapula (Crowe & Elhassan, 2016). Thus, the early cessation of the LT and SA could make inferior medial border being prominent while moving. Moreover, the shorter muscle deactivation time of MT, LT, and SA effects the force couple and the ability of holding the scapular on the thoracic cage when doing arm elevation, therefore, the presence of inferior angle type scapular dyskinesis were occurred. As well as the previous study of scapular muscle that found an early deactivation time of SA in the shoulder impingement group compared to the control group (Phadke & Ludewig, 2013).

Table 3. Comparison of muscle onset time, muscle deactivation time, and muscle activation time in shoulder flexion between ISD group and NP group

	ISD group[a] (n = 6)	NP group[a] (n = 6)	Mean difference (95% CI)	p-value[b]
Muscle onset time (seconds)				
UT	0.54 (0.37)	0.69 (0.15)	0.15 (-0.02–0.31)	0.067
MT	0.69 (0.14)	0.70 (0.11)	0.01 (-0.16–0.17)	0.947
LT	0.78 (0.17)	0.91 (0.28)	0.13 (-0.16–0.43)	0.347
SA	0.63 (0.14)	0.79 (0.27)	0.16 (-0.11–0.43)	0.219
Muscle deactivation time (seconds)				
UT	5.16 (0.49)	5.65 (0.24)	0.49 (-0.01–0.97)	0.055
MT	5.15 (0.37)	5.66 (0.21)	0.51 (0.12–0.89)	0.015*
LT	4.90 (0.45)	5.58 (0.21)	0.68 (0.20–1.15)	0.012*
SA	4.72 (0.78)	5.45 (0.30)	0.73 (-0.09–1.54)	0.074
Muscle activation time (seconds)				
UT	4.62 (0.44)	4.96 (0.28)	0.34 (-0.12–0.81)	0.133
MT	4.46 (0.34)	4.96 (0.24)	0.50 (0.12–0.89)	0.015*
LT	4.12 (0.54)	4.67 (0.30)	0.55 (-0.01–1.10)	0.055
SA	4.09 (0.73)	4.66 (0.4)	0.57(-0.21–1.33)	0.136

ISD group = inferior angle type of scapular dyskinesis group, NP group = normal pattern of scapula, [a]mean (SD), [b]independent *t*-test, *significant difference between group ($p < 0.050$)

Table 4. Comparison of muscle onset time, muscle deactivation time, and muscle activation time in shoulder scaption between ISD group and NP group

	ISD group[a] (n = 6)	NP group[a] (n = 6)	Mean difference (95% CI)	p-value[b]
Muscle onset time (seconds)				
UT	0.63 (0.16)	0.70 (0.21)	0.07 (-0.16–0.31)	0.495
MT	0.57 (0.11)	0.66 (0.13)	0.09 (-0.06–0.24)	0.217
LT	0.64 (0.07)	0.80 (0.25)	0.16 (-0.99–0.41)	0.183
SA	0.64 (0.20)	0.79 (0.29)	0.15 (0.17–0.47)	0.331
Muscle deactivation time (seconds)				
UT	5.66 (0.21)	5.55 (0.28)	0.11 (-0.42–0.21)	0.466
MT	5.58 (0.20)	5.52 (0.22)	0.06 (-0.32–0.20)	0.616
LT	5.07 (0.40)	5.58 (0.25)	0.51 (0.07–0.94)	0.025*
SA	4.89 (0.18)	5.55 (0.28)	0.66 (0.35–0.95)	0.001*
Muscle activation time (seconds)				
UT	5.03 (0.14)	4.85 (0.32)	0.18 (-0.50–0.14)	0.237
MT	5.01 (0.21)	4.86 (0.27)	0.15 (-0.46–0.16)	0.302
LT	4.43 (0.39)	4.78 (0.35)	0.35 (-0.12–0.82)	0.132
SA	4.25 (0.34)	4.76 (0.51)	0.51 (-0.52–1.07)	0.071

ISD group = inferior angle type of scapular dyskinesis group, NP group = normal pattern of scapula, [a]mean (SD), [b]independent *t*-test, *significant difference between group ($p < 0.050$)

The previous study showed the association of scapular dyskinesis and shoulder pain in term of the nonspecific response (Ludewig & Reynolds, 2009) and there is not the cause and consequence relationship between the scapular dyskinesis and upper quadrant complaints (Cools *et al.*, 2014). However, scapular dyskinesis could be aggravated by pain and it could lead to the alteration of the scapular muscles (Falla *et al.*, 2004). According to the pain adaptation model theory, the muscles protected themselves from further pain or injury during the period of pain (Cools *et al.*, 2014). For this reason, scapular dyskinesis were mostly found in people who experienced shoulder pain (Kibler *et al.*, 2012) and also frequently identified on the painful side in previous study which is similar to this study.

This study confirmed the alteration in muscle control in inferior angle type scapular dyskinesis individuals with upper quadrant complaints. A possible explanation is that more than four hours daily computer use is associated with the mechanical load of tissues due to poor posture and prolonged muscle contraction (Szeto, Straker, & Raine, 2002) causing micro trauma of the tissue and loss of motor control (Visser & van Dieen, 2006). Furthermore, the chronic pain could link with the maladaptive cortical sensorimotor integration (Taylor & Kerry, 2005) and altered response in the motor cortex resulting in the alteration of the motor control (Woodhouse & Vasseljen, 2008). Therefore, the dysfunction of muscle control could be a consequence from pain and injury (Sterling, Jull, & Wright, 2001).

For the clinical implications of this study, this study suggested that the clinical examination of scapular dyskinesis should be done in people with upper quadrant pain and the active scapular control for scapular orientation training of LT and SA during shoulder scaption, MT and LT muscle during shoulder flexion by introducing the medial and external rotation of the scapula, and balancing force couple of UT muscle during shoulder abduction should be applied during

Table 5. Comparison of muscle onset time, muscle deactivation time, and muscle activation time in shoulder abduction between ISD group and NP group

	ISD group[a] (n = 6)	NP group[a] (n = 6)	Mean Difference (95% CI)	p-value[b]
Muscle onset time (seconds)				
UT	0.63 (0.13)	0.57 (0.11)	0.06 (-0.21–0.09)	0.415
MT	0.57 (0.06)	0.61 (0.13)	0.04 (-0.08–0.17)	0.442
LT	0.76 (0.12)	0.86 (0.18)	0.10 (-0.09–0.29)	0.286
SA	0.74 (0.19)	0.86 (0.21)	0.12 (-0.14–0.37)	0.339
Muscle deactivation time (seconds)				
UT	5.40 (0.17)	5.74 (0.23)	0.34 (0.07–0.58)	0.017*
MT	5.57 (0.28)	5.82 (0.15)	0.25 (-0.03–0.54)	0.082
LT	5.23 (0.51)	5.62 (0.22)	0.39 (-0.12–0.89)	0.120
SA	5.25 (0.38)	5.58 (0.26)	0.33 (-0.07–0.75)	0.101
Muscle activation time (seconds)				
UT	4.77 (0.24)	5.17 (0.18)	0.40 (0.11–0.65)	0.009*
MT	5.00 (0.32)	5.21 (0.15)	0.21 (-0.11–0.52)	0.189
LT	4.47 (0.57)	4.76 (0.33)	0.29 (-0.31–0.89)	0.312
SA	4.51 (0.46)	4.72 (0.36)	0.21 (-0.31–0.75)	0.378

ISD group = inferior angle type of scapular dyskinesis group, NP group = normal pattern of scapula, [a]mean (SD), [b]independent *t*-test, *significant difference between group ($p < 0.050$)

rehabilitation. For non-clinical implication, this study recommended that the muscle onset and deactivation time can be possibly investigated by surface EMG in scapulothoracic muscles, by which the sensitivity is appropriate.

3.1 Limitations of the study

The current study did not consider sex differences between the two groups. Even if there was evidence that descending trapezius could be slower in females than in males (Szucs & Borstad, 2013), this study did not find any differences between genders in UT muscle onset time. The cardiac artifacts may occur in this study due to positioning the electrodes close to the heart, however, the data was high-pass filtered with cut-off frequency at 30 Hz to remove noise from movement and heartbeat (Hermens *et al.*, 2000). This study did not provide kinematic data of the scapular dyskinesis but recruited the obvious inferior angle of scapular dyskinesis instead. Although, pain could be a confounding factor on some activities, this study provided the activities that were not limited by pain.

4. Conclusions

This study investigated UT, MT, LT, and SA muscle onset time, muscle deactivation time, and muscle activation time during shoulder scaption focusing on individuals with inferior angle type of scapular dyskinesis who had the upper quadrant complaints and confirming the alteration of LT, and SA muscle control especially during shoulder scaption.

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