

Effects of Posture Correction Exercise on Muscle Activity and Onset Time during Arm Elevation in Subject with Forward Head and Rounded Shoulder Posture

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| Abstract |

PURPOSE: The aim of this study was to provide evidence for the treatment of Forward Head and Rounded Shoulder Posture (FHRSP) using posture correction exercises by comparing muscle activity and onset time around the neck and shoulder area during an arm elevation task.

METHODS: The subjects were divided into FHRSP (21 persons) and non-FHRSP (19 persons) groups to measure muscle activity and onset time of muscle contraction. Wireless surface electromyography was used to assess the muscle activity and onset time of the right and left sternocleidomastoid (SCM), splenius capitis, anterior deltoid, middle deltoid, serratus anterior, upper trapezius, pectoralis major, and infraspinatus during an arm elevation task. After the pre-measurement, the participants performed the postural correction exercises, and then the post-measurement was conducted.

RESULTS: After the posture correction exercises, there were significant differences in the muscle activity and onset time of all muscles in the FHRSP group. The results of the comparison of the muscle onset time during an arm elevation task demonstrated that after the postural correction exercises, the muscle onset time was significantly reduced in the right and left SCM and left splenius capitis, but there were no significant changes in the onset time of other muscles.

CONCLUSION: The results of this study help us understand the change in muscle activities and muscle contraction onset time in a person with FHRSP when lifting the arm and suggest the relevant basis to apply the posture correction exercise in clinical settings.

Key Words: Forward head, Muscle activity, Onset time, Postural correction, Rounded shoulder

I. Introduction

Forward head rounded shoulder posture (FHRSP) is a combination of anterior head posture consisting of flexion of the lower cervical spine and extension of the upper cervical spine, and anterior shoulder posture consisting of an abduction-protraction combination of the scapula [1]. FHRSP is an important internal factor causing shoulder

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pain and dysfunction [2]. Poor sitting postures can lead to an increase in FHRSP and to changes in scapular position, kinematics, and muscle activity [3]. These changes cause muscle tension and stress around the neck and shoulders, and numbness, pain, loss of function, and various nerve root symptoms in the upper extremities [4]. FHRSP and upper trapezius muscle activity were increased in office workers with neck and shoulder pain [5]. FHRSP was also more common in patients with rotator cuff injuries and subacromial impingement syndrome [6]. According to Malmstrom et al. [7], the flexed posture results in a biomechanical change in arm lifting, which reduces the arm lift angle by up to 15°, reduces the arm lift speed by 8%, and increases the overall peak muscle activity of the upper and lower trapezius, and serratus anterior. The relationship among the FHRSP, neck pain and muscle activity is still debatable. Some researchers reported that neck pain was correlated with head, shoulder, and spine posture [2,5], while others indicated that FHRSP did not always correlate with neck pain [8].

For the functional stability of the scapula, it must be in the proper position, the forces of the muscles around the shoulder must be balanced, and the muscular activities of the shoulder rotator cuff muscles should occur in the proper order. The recruitment order of instantaneous muscles and the level at which each muscle is activated during movement are very important factors in controlling shoulder movement when lifting the arm [9]. Because the scapula plays an important role in regulating the position of the glenoid cavity, small changes in muscle activity around the shoulder also affect joint alignment and the force required to move around the shoulder joint [10]. An appropriate neuromuscular contraction strategy is necessary to stabilize the shoulder and minimize anterior tilting when raising the arms. If these neuromuscular patterns are not appropriate, the risk of shoulder impingement syndrome increases [11].

FHRSP must be assessed accurately in the clinic because

even subtle changes in FHRSP can also affect the shoulder's range of motion and muscle activity [12]. So far, most studies have been conducted on peripheral muscle activity in FHRSP, but there has been little research on the activity of peripheral muscles combined with functional movement of the arm. Moreover, a limitation in previous studies is the presence of shoulder pain during testing, which makes it difficult to prove if differences in muscle activity, or posture are the cause of underlying shoulder pathology or are the result of shoulder pain. Furthermore, most studies were performed on the coronal plane, which is a non-functional movement plane, so there was a limitation in accurately measuring the muscle activity of the surrounding muscles during the actual lifting task [13].

FHRSP can be corrected through training. Postural correction can improve the function of the shoulder or reduce the risk of shoulder pain. Therefore, it is very important to understand the effect of FHRSP on shoulder movement and muscle activity [14]. In addition, it is possible to increase joint movements, muscle activity, and physical discomfort while handling objects by hand in a sitting position. Therefore, to prevent the potential risk of musculoskeletal injuries, the effect of FHRSP in a sitting position must be analysed [15].

The purpose of this study was to provide a basis for the treatment of FHRSP by comprehensively analyzing changes in muscle activity and onset time of muscle contraction during functional arm lifting through FHRSP correction.

II. Materials and Methods

1. Subjects

The subjects of this study were 40 men in their 20s in the Seoul Gyeonggi area. The subject selection criteria were as follows: (1) no neck injury, such as herniated intervertebral disc, spondylosis, radiculopathy, chronic headache, torticollis, deformity, strain or whiplash; (2) no

shoulder injury or surgical history, such as subacromial impingement syndrome, rotator cuff injury, bursitis, instability, dislocation or adhesive capsulitis; (3) a person who could raise their arm more than 90° without pain; (4) no neck fractures or spine fractures; and (5) no functional or structural scoliosis [16-18].

Prior to commencing this study, the subjects were fully informed about the purpose of the study and the procedure and signed a written consent form. The overall progress plan of this study was adhered to the ethical principles of the Declaration of Helsinki. This study was conducted according to the guidelines of the Eulji University Institutional Review Board (EUIRB2015-26). This study was conducted from August to December 2015.

2. Research Design

This study had a case control design. The subjects were divided into FHRSP (21 persons) and non-FHRSP (19 persons) groups to measure muscle activity and onset time of muscle contraction. After the pre-measurement, a physical therapist with 10 years' experience performed the posture correction exercise for 10 min. After 1 min of this exercise, muscle activity and onset time of muscle contraction were measured again in the same way, taking into account the physiological adaptation time to the corrected posture [19].

1) Number of Target Subjects

Based on previous studies [16], the number of subjects was calculated using G*power 3.1.9.2 (α -error: .05, power: .80), and the number of subjects required for each group was 16 (effect size; 1.04, actual power; .81). The dropout rate was assumed to be 20%, and the number of subjects per group was set at 20.

2) Subjects and Groups

The forward head angle (FHA) measured the angle between the line connecting the tragus and the C7 spinous

process and the line passing through C7 vertically. The forward shoulder angle (FSA) measured the angle between the line connecting the acromion and the C7 spinous process and the line passing through C7 vertically. Based on these, the measurement criteria for the non-FHRSP group was $FHA < 36^\circ$ and $FSA < 22^\circ$, while those of the FHRSP group were $FHA > 46^\circ$ and $FSA > 52^\circ$ [16].

3) Measuring Equipment

For FHRSP measurements, the Bodystyle s-8.0 (LU trading, Korea), a body-somatotype measuring system, was used. Markers were attached to the tragus, acromion, and C7 spinous process, and the FHA and FSA were measured on the coronal plane. As a result of measuring the reliability of the Bodystyle s-8.0 device, the FHA showed a high level of reliability with $ICC = .98$ and the FSA with $ICC = .99$. The posture measurement method using the photographic method is known to be the most discriminating method in FHA and FSA measurement [18]. The muscle activity was measured with the TeleMyo DTS (Noraxon, USA), with an electrode area of 4 cm × 2.2 cm, diameter of 1 cm, and electrode distance of 2 cm.

3. Measurement Methods

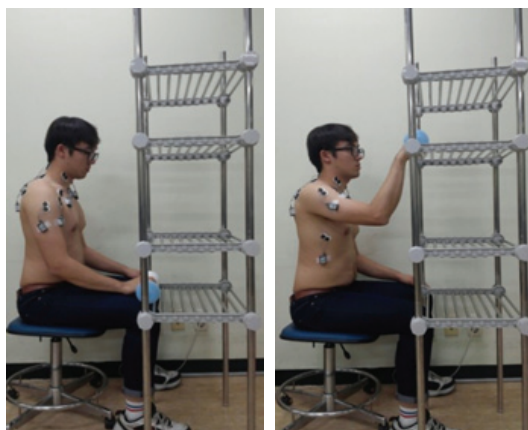
1) Measurement Procedure

All muscle activities were measured while placing objects on a shelf at eye level. Measurements were carried out in a sitting position, and the subjects were measured at a knee angle of 90° using a chair with adjustable height. During the measurement, the chair was fixed firmly to the floor with a fixing device. The measurement arm was selected as the arm that the subject mainly used to throw a ball. The subjects performed the action of placing the object on the shelf at the level of the iliac crest and at eye level (Fig. 1).

The object was placed on the same sagittal plane as the scapular acromion of the measuring arm, and the weight



(a)



(b)

Fig. 1. Measurement procedure for functional arm elevation before (a) and after (b) posture correction exercise

of the object was 3% of the subject's weight to keep the weight ratio lifted by the weight of the subject [16,20].

The horizontal distance between the subject and the object was defined as the distance between the edge of the shelf and the finger when the elbow was bent at 90°. To maintain a constant speed while placing things on the shelf, we used a beep sound at 1-s intervals, which is a program function built into the electromyography (EMG) equipment. Both groups were measured once in a natural posture, and again after the posture correction exercise by the therapist.

2) Measurement of Muscle Activity and Onset Time of Muscle Contraction

Based on previous studies, we selected the muscles that are likely to undergo kinetic changes and activity changes due to FHRSP. Among them, muscles that are difficult to measure with surface electromyography equipment were excluded [1,16,21-26]. In this study, a total of nine muscles were used: the right and left sternocleidomastoid (SCM), splenius capitis, anterior and middle deltoid, upper trapezius, serratus anterior, pectoralis major, and infraspinatus; the specific locations of attachment are shown in Table 1. EMG signals were collected at a sampling rate of 1,000 Hz using MR-XP 1.08 Master Edition (Noraxon, USA) software, and bandpass filters (20-250 Hz) and reject filters (60 Hz) were used to remove noise. The collected EMG signals were analyzed using a root mean square of 200 ms.

All movements were measured three times each, and the mean value of the measurements was used in this study. The % RVC (Reference Voluntary Contraction) values were used to normalize the EMG signal. The RVC of nine muscles was measured from the manual resistance from one tester and during isometric contraction for 3 s in the sitting position. The mean value of RVC was used after three repetitive measurements. All movements allowed the subject to practice the measurement movements sufficiently in advance. The onset time of activity of each muscle was identified by the earliest time that the EMG activity surpassed the mean baseline activity by three standard deviations and remained above this level for 100 ms [27].

4. Posture Correction Exercise

The posture correction exercise was a combination of pelvic anterior tilting, shoulder external rotation, scapular retraction, and chin-in, followed by a physical therapist's instruction for 10 min immediately after the pre-measurement [28-30].

First, the therapist taught the pelvic anterior-posterior tilt exercise in the sitting position, and the subject moved

Table 1. The Placement of Surface EMG Electrodes

Muscles (9)	Placement of Electrode
Rt/Lt Sternocleidomastoid (2)	1/3 the distance from the sternal notch to the mastoid process [44]
Splenius Capitis	Approximately 2 cm lateral to the 4 th cervical spinous process, over the muscle belly [45]
Anterior Deltoid	One finger width distal and anterior to the acromion [46]
Middle Deltoid	Greatest bulge of the muscle from the acromion to the lateral epicondyle of the elbow [47]
Upper Trapezius	Immediately lateral to a point midway between the spinous process of T1 and the acromion process [33]
Serratus Anterior	Along the mid-axillary line over the 6 th rib [33]
Pectoralis Major	Horizontally, 4 cm medial to the axillary fold [47]
Infraspinatus	2.54 cm inferior to the spine of the scapular at a point midway between the spine of the scapular and the posterior acromion process [33]

accordingly. If the subjects could fully comprehend the movement, they repeated the action without the help of the therapist, and the pelvis was naturally tilted forward and an upright posture was maintained.

Then, the subjects bent both elbows naturally and externally rotated the shoulder joint, with the palm facing outward. At this time, both scapulae were adducted, and the chest was stretched at the same time. Finally, the chin was pulled backward while maintaining the previous two postures. The lower cervical segment, which is relatively moved forward, was pulled slightly backward. The therapist placed the fingers in the cervical spinous process and guided the movement to give the subject a specific understanding of the cervical spine that had to move. The subjects repeatedly practiced this until they could maintain their correct postures.

Each exercise was performed in sequence, and three exercises were performed at the same time. The posture correction exercise combined with the three movements was held for 10 s and repeated 10 times, and this was considered as one set. A total of three sets were performed, and a resting time of 1 min was allocated between the sets. The exercise was accompanied by a deep breathing exercise to naturally allow the lower body to expand sufficiently (Fig. 2) [30].



Fig. 2. Postural correction exercise.

5. Data Processing and Analysis

The paired t-test was used to compare differences in muscle activity and onset time of muscle contraction of the FHRSP and non-FHRSP groups before and after the posture correction, and analysis of covariance (ANCOVA) was used to compare the muscle activity between the two groups. All statistical data were processed using SPSS 18.0, and the significance level was .05.

Table 2. General Characteristics of Subjects (Mean ± SD)

	Non-FHRSP (n = 19)	FHRSP (n = 21)	p	t
Age (year)	22.53 ± 2.63	22.90 ± 2.17	-.50	.63
Weight (Kg)	72.42 ± 9.35	74.62 ± 8.72	-.77	.45
Height (cm)	173.89 ± 4.23	175.62 ± 4.31	-1.28	.21
FHA (°)	28.80 ± 4.70	52.49 ± 6.28	-13.39	.00*
FSA (°)	17.90 ± 6.06	57.76 ± 8.45	-16.98	.00*

FHRSP : Forward Head Round Shoulder Posture

FHA; Forward Head Angle, FSA; Forward Shoulder Angle

Table 3. Changes in Muscle Activity (%RVC) after Postural Correction Exercise

	Non-FHRSP (n = 19)			FHRSP (n = 21)		
	Pre	Post	t	Pre	Post	t
Rt SCM	2.14 ± 1.66	1.90 ± 1.21	1.32	1.98 ± .75	1.78 ± .72	4.17***
Lt SCM	2.60 ± 1.51	2.42 ± 1.09	.98	2.28 ± .73	1.80 ± .71	8.69***
SC	21.20 ± 11.93	21.47 ± 12.53	-.23	22.20 ± 15.81	17.34 ± 12.21	3.74**
AD	32.79 ± 10.82	28.28 ± 9.90	3.43**	33.97 ± 16.06	17.81 ± 4.83	5.85***
MD	19.27 ± 8.64	16.79 ± 7.43	5.27***	23.40 ± 9.60	17.02 ± 7.33	5.27***
UT	53.82 ± 34.43	52.74 ± 31.66	.60	56.60 ± 38.89	46.51 ± 32.40	3.41**
SA	53.64 ± 27.84	54.22 ± 29.38	-.32	44.10 ± 18.43	37.95 ± 17.07	3.22**
PM	28.51 ± 19.59	29.20 ± 18.01	-1.25	29.67 ± 14.61	33.61 ± 13.77	3.34**
IS	26.51 ± 13.20	25.65 ± 12.49	1.61	28.12 ± 20.29	26.16 ± 19.50	2.54*

FHRSP: Forward Head Round Shoulder Posture, SCM: Sternocleidomastoid, SC: Splenius Capitis, AD: Anterior Deltoid

MD: Middle Deltoid, UT: Upper Trapezius, SA: Serratus Anterior, PM: Pectoralis Major, IS: Infraspinatus

*p < .05, **p < .01, ***p < .001

III. Results

1. General Characteristics of the Subjects

This study had a total of 40 subjects: 21 in the FHRSP group and 19 in the non-FHRSP group. All subjects were men and right handed (Table 2).

2. Comparison of Muscle Activity after the Posture Correction Exercise

The activity of the muscles around the neck and shoulders of the non-FHRSP group was significantly different between AD (p < .01) and MD (p < .001) before

and after the posture correction exercise, and the muscle activity of the FHRSP group was significantly different before and after the posture correction exercise in all muscles (p < .05) (Table 3).

To investigate the differences in the activity of the neck and shoulder muscles between the non-FHRSP and FHRSP groups during functional arm lifting after the posture correction exercise, ANCOVA was used to measure the pre-test scores as covariates and the post-test scores as dependent variables. As a result, after posture correction, except for the right SCM and infraspinatus muscles, all the other muscles showed significant differences (p < .05).

Table 4. ANCOVA Computation on Muscle Activity (Post-test) in the Group and Pre-test

Muscles	Sum of Squares	Df	Mean Square	F	p	Partial 2
Rt SCM	.06	1	.06	.24	.63	.007
Lt SCM	1.57	1	1.57	7.80	.01**	.174
SC	243.40	1	243.40	10.04	.00**	.213
AD	1190.08	1	1190.08	39.56	.00***	.517
PD	70.33	1	70.33	5.98	.02*	.139
UT	595.09	1	595.09	8.04	.01**	.178
SA	496.97	1	496.97	6.93	.01*	.158
PM	112.71	1	112.72	7.21	.01*	.163
IS	9.95	1	9.905	1.19	.28	.031

SCM : Sternocleidomastoid, SC Splenius Capitis, AD Anterior Deltoid

MD Middle Deltoid, UT Upper Trapezius, SA Serratus Anterior, PM Pectoralis Major, IS Infraspinatus

*p < .05, **p < .01, ***p<.001

AD was the most affected by the posture correction exercise, and the influence of the posture correction exercise was the highest at 51.7% (Table 4).

3. Comparison of Onset Time of Muscle Contraction

The onset time of muscle contraction during functional arm lifting after the posture correction exercise accelerated the contraction onset time in all muscles. In particular, the right (p < .01) and left SCM (p < .05) and splenius capitis (p < .05) in the FHRSP group before and after the posture correction exercise significantly accelerated the muscle contraction onset time, but did not show a significant difference in the onset velocity of other muscles. In addition, there was no statistically significant difference in the onset time of muscle contraction between the FHRSP and non-FHRSP groups after the posture correction exercise (Table 5).

In the FHRSP group, the pectoralis major contracted most rapidly before the posture correction and contracted in the order of serratus anterior, anterior deltoid, middle deltoid, infraspinatus, upper trapezius, splenius capitis, left SCM, and right SCM muscles. After postural correction, the serratus anterior was the first to contract and showed

the onset time of muscle contraction in the order of pectoralis major, anterior deltoid, infraspinatus, middle deltoid, upper trapezius, splenius capitis, left SCM, and right SCM muscles (Table 6).

IV. Discussion

A specialized posture correction exercise that moves the lumbar and pelvis to a neutral position can increase the recruitment ability of the deep posture muscles throughout the day. Historically, clinicians have taught patients to avoid bending postures and instructed them to maintain the spine in a neutral position when sitting or standing. Clinicians should have a thorough understanding of how to minimize the mechanical load on the musculoskeletal system so that it can promote the recruitment of deeply stabilized muscles in the spine continuously [31].

In this study, there was a significant change in muscle activity after the posture correction exercise in all nine muscles of the FHRSP group during functional arm lifting. In the FHRSP group, the right SCM and infraspinatus muscles showed a significant decrease in muscle activity

Table 5. Changes in Muscle Onset Time after Postural Correction Exercise

	non-FHRSP (n = 19)			FHRSP (n = 21)			t	p
	Pre	Post	t	Pre	Post	t		
Rt SCM	2.04 ± .55	1.90±.47	.79	2.53 ± 1.12	1.94 ± .62	3.08**	-.25	.81
Lt SCM	1.94 ± .50	1.73 ± .48	1.58	2.29 ± .55	1.85 ± .63	2.69*	-.65	.52
SC	1.80 ± .41	1.58 ± .35	1.87	2.01 ± .82	1.69 ± .51	2.23*	-.78	.44
AD	1.13 ± .43	0.96 ± .24	1.76	1.10 ± .55	0.92 ± .42	1.69	.30	.77
MD	1.21 ± .46	1.04 ± .24	1.74	1.30 ± .56	1.13 ± .46	1.53	-.81	.42
UT	1.32 ± .43	1.16 ± .27	1.73	1.36 ± .51	1.34 ± .46	.23	-1.49	.15
SA	0.99 ± .46	0.83 ± .32	1.37	1.04 ± .64	0.86 ± .41	1.20	-.29	.77
PM	1.02 ± .56	0.85 ± .37	1.79	0.97 ± .64	0.91 ± .51	0.50	-.40	.69
IS	1.22 ± .38	1.01 ± .26	2.03	1.27 ± .53	1.08 ± .48	1.75	-.54	.59

SCM : Sternocleidomastoid, SC Splenius Capitis, AD Anterior Deltoid

MD Middle Deltoid, UT Upper Trapezius, SA Serratus Anterior, PM Pectoralis Major, IS Infraspinus

* p < .05, ** p < .01

Table 6. The Sequence of Onset Time in FHRSP Group before and after Postural Correction

FHRSP Group	Rank								
	1	2	3	4	5	6	7	8	9
Pre	PM	SA	AD	MD	IS	UT	SC	Lt SCM	Rt SCM
Post	SA	PM	AD	IS	MD	UT	SC	Lt SCM	Rt SCM

PM: Pectoralis Major, SA: Serratus Anterior, AD: Anterior Deltoid, MD: Middle Deltoid

IS: infraspinus, UT: Upper Trapezius, SC: Splenius Capitis, SCM: Sternocleidomastoid

after the posture correction exercise, but there was no significant difference in muscle activity change compared to the non-FHRSP group. In other words, the posture correction exercise is effective in decreasing muscle activity of the right and left SCM muscles in patients with FHRSP. Lee et al. [32] suggested that posture correction exercises, such as pilates, were helpful in reducing the fatigue of SCM in patients with forward head posture. Similar to our results, Lopes et al. [33] reported no significant difference in the activity of the infraspinus muscle in the group with scapular dyskinesis compared to the group without scapular dyskinesis in the arm lifting of patients with subacromial impingement syndrome.

Left SCM and splenius capitis showed significant

decreases in muscle activity in the FHRSP group after postural correction and significant differences in the non-FHRSP group. Therefore, the posture correction exercise proved to be effective in reducing FHRSP by decreasing the activity of the left SCM and splenius capitis. Generally, when lifting the arm, the head is rotated slightly in the same direction due to gaze, and the opposite SCM is activated more than the ipsilateral SCM. Previous studies [34-37] have focused on the ipsilateral SCM muscle of the same side of the arm. In this study, we measured both SCMs and found that the activity of the left SCM of the FHRSP group was significantly lower than that of the non-FHRSP group after the posture correction exercise. Therefore, the results of this study suggest that SCM muscle

activity related to the arm-lifting movement should include both muscles.

The anterior deltoid and middle deltoid showed significant decreases in muscle activity after the posture correction exercise in both non-FHRSP and FHRSP groups, and there was a difference in muscle activity between the two groups. These results suggest that FHRSP as well as non-FHRSP can reduce unnecessary muscle activity of the anterior and middle deltoid after the posture correction exercise. The anterior and middle deltoid act as the main muscles when lifting the arms. If the activity of these two muscles is increased, lifting the arm will increase the pressure on the joints and delay the activity of the rotator cuff muscles, while pulling the humerus closer to the acromion, increasing the risk of impingement syndrome [10]. Therefore, the posture correction exercise is thought to reduce the anterior deltoid and middle deltoid muscle activity, which may help prevent impingement syndrome.

In the present study, the muscle activities of the upper trapezius and serratus anterior were significantly reduced in the FHRSP group after postural correction, and a significant difference was found in the non-FHRSP group. These two are very important muscles that move the scapula with an upward rotation that enables the movement of the humerus while lifting the arms [38]. Kinematically, when the length of the upper trapezius is shorted and serratus anterior muscle is stretched due to FHRSP, it does not produce sufficient upward rotation of the scapula during arm lifting, which increases the action of the anterior deltoid and middle deltoid and increases the burden on the shoulder joints [10]. Moreover, the posture correction exercise can reduce the pressure applied to the shoulder joint by correcting the downwardly rotated scapula to its normal position and reducing the load of the upper trapezius and serratus anterior muscles. In previous studies [16,39], the activity of the serratus anterior muscle was decreased in the FHRSP group, but in the present study, the activity of the serratus anterior muscle was increased before posture

correction and it decreased after the posture correction. The serratus anterior muscle plays a role in making and controlling the rotation and tilt of the scapula. When the levator scapula is shortened and the downward rotation of the scapula is increased due to FHRSP in the sitting position the serratus anterior muscle should have more contraction force due to the relatively increased length when lifting the object [10]. Therefore, when the scapula is repositioned to normal after the posture correction exercise, the muscle can be lifted with a lesser effort, as its length becomes normal. Hundza et al. [40] reported that subjects with unstable shoulder joints had significantly increased activity of the serratus anterior muscle when lifting the shoulder joint to 90° during the arm-cycling movement, which is consistent with our results.

In the present study, there was a difference in the upper trapezius muscle activity between the non-FHRSP and FHRSP groups before and after the posture correction exercise. Weon et al. reported that the upper trapezius muscle activity was higher in FHRSP than in the normal posture during isometric bending at 90° to 2 kg weight, and posture correction could reduce the muscle activity of the upper trapezius muscle [41]. This result is in agreement with the result of this study. Therefore, the posture correction exercise may be effective in raising arms at eye level.

In this study, we hypothesized that the muscle activity of subjects with FHRSP after the posture correction exercise in the functional arm-lifting task would be reduced compared with that before the correction exercise. As a result, all the eight muscles, except for the pectoralis major muscle, had decreased muscle activity after the posture correction exercise. However, the activity of the pectoralis major muscle increased significantly after posture correction. In this study, the clavicle head portion of the pectoralis major muscle was measured, and this area was the most active muscle at the beginning of arm flexion.

Moreover, in this study, muscle activity was measured

while placing objects on the shelf at eye level. In the FHRSP group, the relative height of the shelf was higher due to the bent posture, and as the angle of the arm was increased, the muscle activity decreased in the clavicle head portion of the pectoralis major muscle. However, after the posture correction exercise, the height of the shelf was relatively low, and the action of the pectoralis major muscle appeared to be slightly increased while placing the object on the shelf.

In this study, we compared the onset time of muscle contraction during functional arm lifting after FHRSP correction and found that it was faster in all muscles. In particular, the right and left SCM and splenius capitis accelerated the onset time of muscle contraction. In other words, FHRSP posture correction exercises can help correct and stabilize the head and neck alignment preferentially during arm lifting, because the muscles around the neck, such as the right and left SCM and splenius capitis, contract faster than before the posture correction.

In this study, we analyzed arm lifting for 1 s during flexion of the shoulder joint. There was no difference in the onset time of the muscles around the shoulder after the posture correction exercise. In Hodges and Richardson's study [42], there was no significant difference in the muscle contraction onset time between the shoulder and trunk muscles during fast and normal speed movements of arm lifting.

In this study, when the subjects with FHRSP lifted their arms, the pectoralis major muscle contracted first, and other muscles were recruited sequentially, whereas the serratus anterior contracted first after the posture correction exercise. Wattanaprakomkul et al. [43] found that the serratus anterior muscle contracts first in lifting 20% of 1RM in normal subjects, which is consistent with our results. In addition, the middle deltoid in FHRSP was recruited before the infraspinatus, but the infraspinatus contracted faster than the middle deltoid after postural correction. This result suggests that the posture correction exercise may help

stabilize the scapula and reduce the compression force of the glenohumeral joint during arm lifting.

There were some limitations of this study. First, it is difficult to generalize the results of this study because the number of subjects is small and is limited to men in their 20s. Second, we did not measure muscle activity for deep neck and shoulder muscles such as suboccipital muscles, levator scapular muscle, and supraspinatus muscle because we used surface EMG for muscle activity measurement.

V. Conclusions

This study demonstrated that the posture correction exercise can positively affect the activity of the muscles around the neck and shoulders during functional arm lifting in a person with FHRSP. The results of this study help us understand the change in muscle activities of each muscle when lifting the arm and suggest the relevant basis to apply the posture correction exercise in clinical settings. This study also confirmed that the muscle contraction onset time changes in some muscles during arm-lifting movement after the posture correction exercise.

In the future, we need to analyze the functional arm-lifting movement in a standing posture or in various postures. In addition, studies on activation and contraction onset time of muscles, which are difficult to measure by surface EMG, should also be conducted.

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