한국전문물리치료학회지 2018년 25권 1호 62-70 ISSN (Print) 1225-8962, ISSN (Online) 2287-982X
Phys Ther Korea 2018;25(1):62-70 https://doi.org/10.12674/ptk.2018.25.1.062

A Comparison of Shoulder Muscle Activities on Sitting Posture and Shoulder Angle

Gyeong-ju Park, Sun-young Park, Eun-jae Lee,
Su-hyeon Jeong, Su-jin Kim, PhD, PT
Dept. of Physical Therapy, College of Medical Science, Jeonju University

Abstract

Background: Sitting posture influences movements of scapulothoracic and glenohumeral joints and changes the shoulder muscle activities. The development and maintenance of correct sitting posture is important for the fundamental treatment of shoulder pain during rehabilitation.

Objects: The purpose of this study was to investigate the effects of the sitting postures and the shoulder movements on shoulder muscle activities for both male and female.

Methods: Twenty-eight subjects without shoulder-related diseases participated in this experiment. The subjects had randomly adopted three different sitting postures (upright posture, preferred posture, maximum slouched posture) and shoulder flexion angles in scapular plane (30˚, 90˚, 120˚). Surface electrodes were collected from upper trapezius (UT), anterior deltoid (AD), and posterior deltoid (PD) and the active shoulder range of motion was measured in each sitting posture and shoulder flexion angle.

Results: The active range of motions of the shoulder external rotation and the flexion in the scapular plane decreased from the upright posture to the maximum slouched posture ($p<.05$, mixed-effect linear regression with random intercept, Tukey post-hoc analysis). All muscles showed the highest EMG activities at 120˚ shoulder flexion with the maximum slouched posture and did not show the gender differences.

Conclusion: Increased shoulder muscle activities may become the potential risk factor for the shoulder impairment and pain if people continuously maintain the maximum slouched posture. Therefore, an upright position is necessary during shoulder exercises, as well as in activities of daily living, including motions involving lifting the arms.

Key Words: Electromyogram; Muscle activity; Shoulder range of motion; Sitting posture.

Introduction

Because many of today's routine activities, such as working on a computer, reading a book, or using a smartphone, are performed while seated, individuals are increasingly subjected to prolonged periods of sitting (Brookham et al, 2010; Pascarelli and Hsu, 2001). These activities are performed in atypically flexed postures, known as slouched sitting posture, result in abnormally aligned thoracic and lumbar vertebrae and, consequently, in changes in the position and biomechanical properties of the shoulder complex, including the scapulothoracic and glenohumeral joints (Lee et al, 2016).

Slouched sitting posture refers to a pelvic posterior rotation and flexed thoracolumbar trunk that is often combined with a forward head posture and rounded shoulder (Culham and Peat, 1993; O'Sullivan et al, 2006). During an upright sitting posture, the scapula is normally aligned on the thoracic wall in a position that is slightly elevated, retracted, and in an upward rotation (Neurmann, 2017). As the arm is elevated, the scapula is upwardly and externally rotated and is posteriorly tilted (Ludewig et al, 1996; Ludewig and Cook,

Corresponding author: Su-jin Kim sujink@jj.ac.kr

2000; Ludewig and Reynolds, 2009). Slouched sitting alters scapular kinematics: The scapula experiences less posterior tilting and less external rotation during shoulder flexion in the scapular plane (Kebaetse et al, 1999). In addition, it influences shoulder range of motion (ROM): the shoulder abduction and flexion angles in the scapular plane decrease by approximately 15°-24° and 16°-18°, respectively (Kanlayanaphotporn, 2014). This limited range of motion in the shoulder joint restrains the upper extremity's functional movement (e.g., dressing, grooming, and bathing) (McLean, 2005) and results in abnormal muscle contractions (Alizadehkhaiyat et al, 2015).

Because an altered scapular position caused by slouched posture is linked to various symptoms, such as forward head posture syndrome and shoulder impingement syndrome, many researchers have studied slouched posture and arm elevation with and without such syndromes. Nairn et al (2013) measured the kinematics and electromyographic (EMG) activities of trunk muscles during upright, slumped, and maximally trunk-flexed sitting postures and found that slouched sitting increased 10° of posterior pelvis rotation and decreased 3% of the lower thoracic erector spine muscle activity. Another study reported a decreased shoulder ROM during slouched sitting posture (Kanlayanaphotporn, 2014). More recently, scapular muscle activities were measured during slouched sitting at 90° of shoulder abduction; the authors found that the muscle activities of the middle and lower trapezius during slouched sitting posture increased more significantly than in an upright sitting posture (Lee et al, 2016). However, the aforementioned studies analyzed slouched sitting compared to upright sitting in terms of trunk and shoulder ROM (Bullock et al, 2005; Caneiro et al, 2010; Finley and Lee, 2003; Kanlayanaphotporn, 2014; Nairn et al, 2013) or the muscle activities of scapular muscles during arm elevation without slouched posture (Ekstro et al, 2003; Nagai et al, 2013). Furthermore, despite the fact that many daily activities involving the upper extremity in the home (e.g., hair combing, dressing, and grooming) and at the workplace (e.g., lifting objects and placing them on shelves or holding tools such as drills and hammers in an upright position for extended periods of time) require shoulder elevation, no studies to date have explored scapular and shoulder muscle activities at shoulder elevations exceeding 90°. In addition, since ROM for the shoulder joint during slouched sitting have been measured only in men and not in women, it remains unclear how slouched sitting posture differs based on gender. Because the gender difference in shoulder ROM, shoulder muscle fatigue, and shoulder impingement and pain are often reported, different gender may or may not differently respond to slouched sitting posture. Therefore, in this study, we measured the active range of motion (AROM) of the shoulder joint as well as the scapular and shoulder muscle activities of both men and women in multiple sitting postures and shoulder flexion angles.

Methods

Subjects

Twenty-eight healthy young adults (15 females and 13 males) were recruited for this study. The general characteristics of the subjects are shown in Table 1. The exclusion criteria for participants included the following: history of upper-extremity surgeries or other musculoskeletal problems, symp-

Table 1. General characteristics of subjects (N=28)

	Male (n_1=15)	Female (n_2=13)
Age (year)	21.4±1.77[a]	20.5±.52
Height (㎝)	175.6±3.76*	160.8±5.21
Weight (㎏)	74±11.75*	53.5±5.29

[a]mean standard±error, *difference between male and female(p<.05).

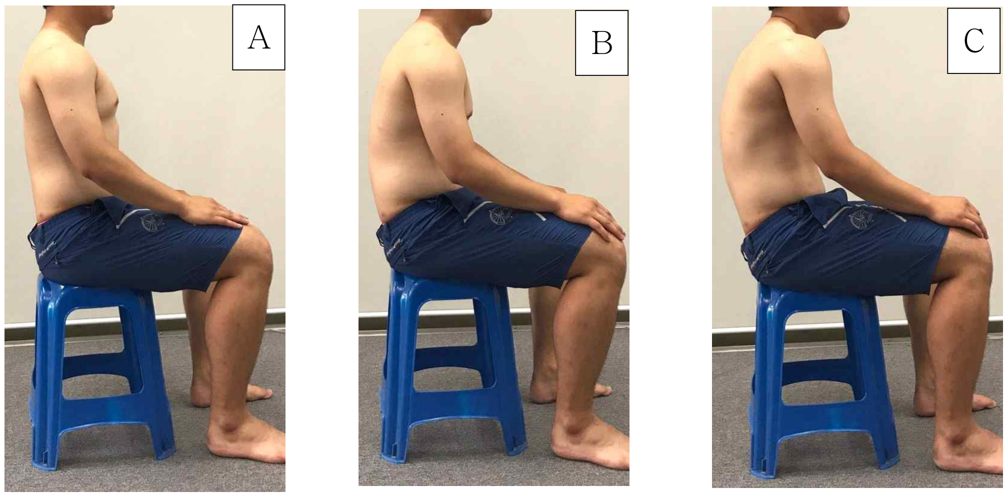

Figure 1. Three different sitting postures. (A) Upright posture, (B) Preferred posture, (C) Maximum slouched posture.

toms of pain in an upper extremity at the time of testing as measured by the visual analog scale (score<2), and negative Neer and Hawkins-Kennedy tests for shoulder impingements (Kanlayanaphotporn, 2014). After the testers explained the study, all subjects agreed to participate in the experiments and signed informed consents.

Experimental design

(1) Experimental protocol

After the participants signed their informed consents, the shoulder AROM of internal and external rotation and flexion in the scapular plane were measured during upright, preferred, and maximum slouched sitting postures (Figure 1). After AROM measurements, they were asked to flex their shoulder at three different angles (30˚, 90˚, and 120˚ shoulder flexion in the scapular plane) in three different sitting posture (Figure 2). Three different sitting postures and three difference shoulder angles were randomly ordered using the Latin square method. All dependent variables, such as EMG activity and AROM of the shoulder joints were evaluated using each participant's right arm.

(2) Sitting postures

During the upright sitting posture, the subjects sat straight on the chair without a backrest and placed both feet on the ground with 90˚ of knee flexion. During the preferred sitting posture, the subjects sat on the chair as they usually did during their daily activities; during maximum slouched sitting posture, they maximally slumped their shoulders, thoracic, and lumbar spines. In every trial, rulers were used to measure thoracic length, the distance between the 7th cervical vertebral and the 12th thoracic vertebra. This minimized unintended changes in posture during repeated measurements and confirmed that our subjects successfully made different sitting postures.

(3) Shoulder flexion angles in scapular plane

Shoulder flexion angles in scapular plane were defined as the angle between the anterior axillary line of the trunk and the longitudinal line of the humerus. All subjects were asked to horizontally adduct 30˚ their shoulder joints to place shoulders and arms in the scapular plane, and a board was used to maintain the shoulder position (Figure 2). Each subject performed 30˚, 90˚, and 120˚ shoulder flexion in the scapular plane in three different sitting posture.

Measurements

(1) Active range of motion of the shoulder joint

To determine the effects of sitting posture on

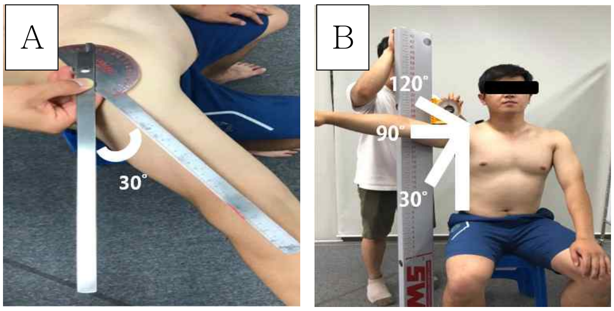

Figure 2. Shoulder flexion in scapular plane. Scapular plane was defined as 30° of horizontal shoulder adduction (A) and the subjects flex shoulder at 30°, 90°, and 120° in scapular plane.

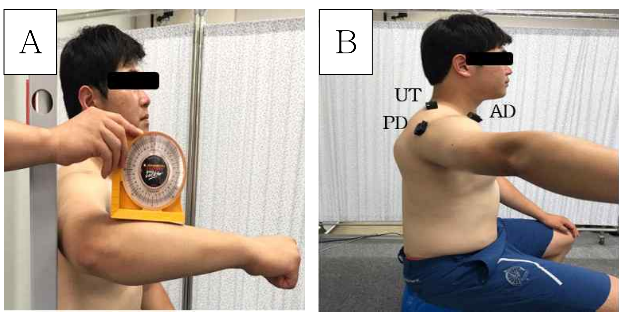

Figure 3. Assessment for shoulder AROM and EMG attachments. (A) AROM for shoulder internal rotation in scapular plane, (B) Surface EMG attachment sites.

AROM in the shoulder joint, the AROM of internal rotation and external rotation of the shoulder joint was measured using a goniometer (JAMAR Goniometer, Performance Health, IL, USA) at 90° of shoulder flexion in the scapular plane (Figure 3). Internal and external shoulder rotation in the scapular plane was measured using an inclinometer (Johnson Magnetic Inclinometer, Datacomm Express, Alagomeji-Yaba, Nigeria) placed on the forearm, with 90° of elbow flexion. The full AROM of shoulder flexion in the scapular plane was measured using the same device placed on the upper arm. To minimize tester measurement errors, one experienced tester completed all measurements of thoracic length and AROM of the shoulder joints.

(2) Electromyography activities

Surface electromyography (EMG) (Trigno™ wireless EMG, Delsys, USA) was used to record activities in the upper trapezius (UT), anterior deltoid (AD), and posterior deltoid muscles (PD) (Figure 3). The locations for the electrodes followed previous study (Ekstrom et al, 2003). To diminish impedance on the skin, the areas for the electrodes were shaved and cleaned with alcohol before the electrodes were placed. EMG data were sampled at 1000 ㎐, filtered with a band-pass filter between 50 ㎐ and 200 ㎐, rectified, and root-mean squared. To minimize tester errors, one experienced tester attached the electrodes to all the subjects. Maximum voluntary isometric contraction (MVIC) was measured twice for each muscle after two or three trials of practice. Each MVIC was recorded for 5 seconds, and data from the middle 3-second of the MVIC were used. The MVIC recordings were completed at 3-minute intervals to prevent potential muscle fatigue. Because the first and second values of the MVIC were not statistically different (paired t-test, $p>.05$), the mean value of the first and second MVIC was used for further analysis. After the MVIC recordings, the subjects changed their sitting postures and shoulder angles in the scapular plane according to the order from the Latin square method. EMG activities were recorded twice for 5 seconds in each sitting posture and shoulder angle. Like the procedure used with the MVIC, the data from the middle 3 seconds were used for further analysis. The inter-trial interval was 1 minute, and the total experiment time was approximately 30-40 minutes.

Statistical analysis

All statistical analyses were carried out using R statistical software. Differences in AROM of internal rotation, external rotation, and flexion in the scapular plane for all sitting postures and for both genders were analyzed using mixed-effect models, with the individuals considered to be random effects. Post-hoc analyses were performed using Tukey's test, which corrects for multiple comparisons. In addition, differ-

Table 2. Shoulder range of motion at different sitting postures (N=28)

		Upright	Preferred	Max. Slouched[a]
Flexion in scaption plane (°)	Female	153.92±2.54[b]	142.23±3.40†	117.15±9.06†
	Male	164.47±3.42*	147.13±3.66*†	131.20±2.72*†
Internal rotation (°)	Female	54.23±2.56	57.46±2.56†	64.30±3.45†
	Male	46.07±3.20	54.33±3.97†	61.60±3.14†
External rotation (°)	Female	99.07±3.34	96.00±2.35†	84.31±3.34†
	Male	95.20±5.11*	85.00±4.11*†	72.07±2.64*†

[a]maximum slouched, [b]mean±standard error, *significant difference between men and women ($p<.05$), † significant difference between upright and preferred and upright and max posture ($p<.05$).

ences in EMG activities for each muscle across sitting postures, shoulder flexion angles, and gender were analyzed using mixed-effect models, as the sitting postures, shoulder flexion angles, and gender were fixed factors, and each individual was considered to be a random factor. Tukey's test was used for multiple comparisons if post-hoc analyses were required. The statistical significance level was set at .05.

Results

Table 2 represents shoulder joint AROM across three different sitting postures and for both genders. Compared to the upright sitting posture, both the preferred and maximum slouched sitting postures showed decreased AROM of shoulder external rotation and flexion in the scapular plane in both women and men men ($p<.05$, mixed effect linear regression). Post-hoc analysis further revealed that, for both women and men, the maximum slouched sitting posture was associated with a statistically higher shoulder external rotation and flexion in the scapular plane than the preferred sitting posture ($p<.05$ tukey post-hoc test). In contrast, shoulder internal rotation was lowest in the maximum slouched sitting posture, followed by the preferred and the upright sitting postures ($p<.05$, mixed effect linear regression). Male subjects showed higher shoulder flexion and lower external rotation than female subjects.

The UT, AD, and PD activities in the upright, preferred, and maximum slouched sitting postures are shown in Figure 4 and Figure 5. There were no differences between men and women in terms of muscle activities. All muscles showed maximal muscle activations at 120° of shoulder flexion during sitting in maximum slouched posture ($p<.05$, mixed effect linear regression). Specifically, muscle activations of the UT increased as the shoulder flexion angle increased and sitting posture changed from upright to maximum slouched. Muscle activation of the AD increased only with increases in the shoulder flexion angle but not with the sitting posture. In addition, PD muscle activity changed only with the sitting posture but not with shoulder flexion angle.

Discussion

Prolonged slouched sitting posture influences not only the normal alignment of scapulae but also the fatigue and pain level of shoulder joints during arm movements. Thus, this study researched the effects of upright, preferred, and maximum slouched sitting postures on the muscle activities of scapular shoulder muscles and on the AROM of shoulder joints during shoulder flexion in the scapular plane in young male and female adults. The main findings revealed that the shoulder internal rotation and muscle activities of the UT and PD increased when study participants assumed the maximum slouched sitting postures. In addition, UT and AD muscle activations increased as the shoulder flexion angle increased. There were no gender differences in EMG activities, but male subjects showed higher shoulder flexion and lower external rotation than female subjects.

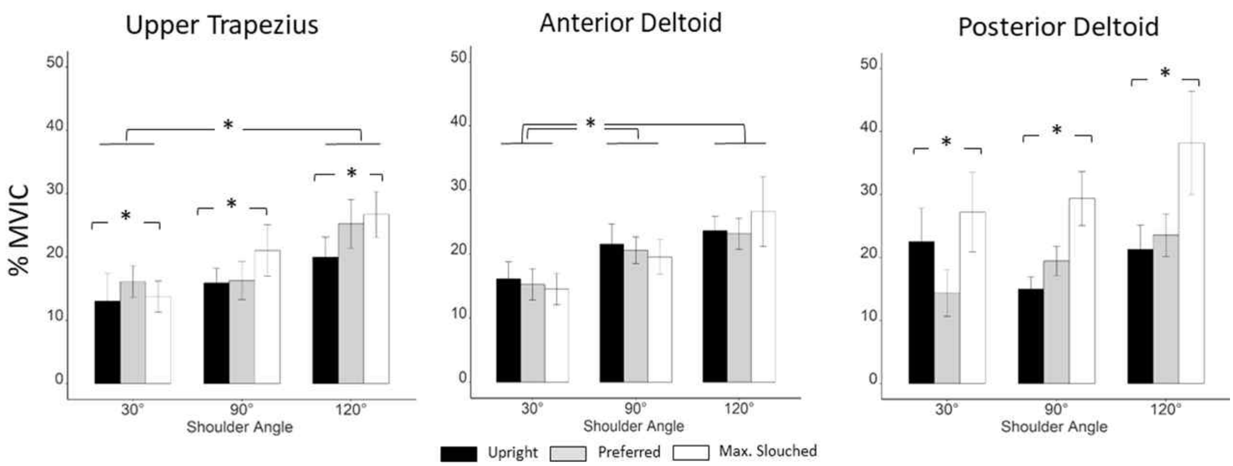

Figure 4. In male subjects, muscle activities (%MVIC) for upper trapezius, anterior deltoid, and posterior deltoid during shoulder flexion with different sitting postures. *indicates statistically significant differences.

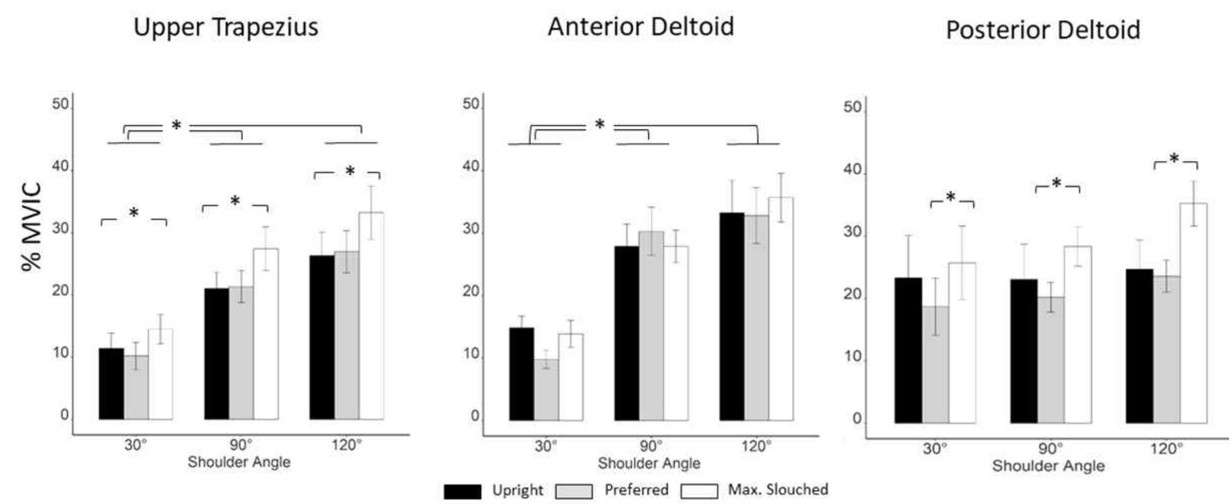

Figure 5. In female subjects, muscle activities (%MVIC) for upper trapezius, anterior deltoid, and posterior deltoid during shoulder flexion with different sitting postures. *indicates statistically significant differences.

From the upright to the maximum slouched postures, shoulder internal rotation increased while shoulder external rotation and flexion in the scapular plane decreased. These results are similar with previous studies showing 30% of decreased external rotation ROM and 20% of increased internal rotation ROM from the upright to the slouched sitting postures in male subjects (Kanlayanaphotporn, 2014). In the maximum slouched posture, the scapular tilted anteriorly, resulting in an "automatic change" of the initial position (Kebaetse et al, 1999). Thus, the humerus is already in external rotation, resulting in decreased shoulder external rotation ROM. On the other hand, due to this increased initial position with an externally rotated shoulder, the internal rotation of shoulder increased when participants assumed the maximum slouched posture.

Muscle activities were not demonstrated to be significantly different between men and women. According to the previous study, female and male did not show different muscle activities of upper trapezius during static shoulder contraction. However, during eccentric shoulder contraction, male subjects showed higher muscle activity than female subjects. Because our study measured muscle activities during static shoulder contraction as like previous study, we might not find gender effect on EMG activities.

The effects of sitting posture and the shoulder flexion angle on muscle activities were observed in all muscles. The UT showed increases in muscle activities in the maximum slouched posture compared to those occurring in the upright posture. These results are in line with the previous research showing that UT muscle activities increased as the shoulder girdle elevated (Sciascia et al, 2012; Uga et al, 2016) and as the subjects were sitting with maximally slouched posture (Schüldt et al, 1986). However, other studies have reported opposite results, indicating that muscle activities of UT did not change with respect to the sitting posture (Caneiro et al, 2010), therefore, the effects of slouched posture on shoulder muscle activities need to be further explored. One possibility for the differences in study findings is that the slouched sitting posture itself may not have a deep impact on UT muscle activities. Together with arm elevation, UT increases muscle activities during slouched sitting posture. The results of the present study support the assumption that UT muscle activation increased in the maximum slouched posture, not only in 120° of shoulder flexion, but also in 30° of shoulder flexion in the scapular plane. In considering the sitting postures and arm movements of sedentary workers and students, the slight 30° of shoulder flexion and maximum slouched sitting posture are commonly observed, requiring a keen interest in UT muscle activities. If UT muscle activities remain active for extended periods of time when the individual is in a slouched posture and has an elevated arm, the result might be muscle fatigue and, eventually, a continuous strain on that muscle (Malmströmm et al, 2015).

The AD showed the highest level of muscle activities in 120° of shoulder flexion; however, there were no changes in muscle activities based on sitting posture. These results are in line with previous studies which reported that muscle activity of the AD increases as the arm elevates (Liu et al, 1997). When arm is elevated, internal moment arm is increased as well, thus, the AD muscle activity is increased. Conversely, the muscle activation of the PD was, among the different sitting postures, the highest level in maximum slouched posture, but there were no changes with respect to the shoulder flexion angle. Since the PD, unlike the anterior and middle deltoids, is not a primary arm-elevation muscle, it acts as an antagonist during abduction but gradually becomes the agonist at higher elevation angles (Liu et al, 1997). Consistent with previous studies, 120° of arm elevation in our study, did not have a significant impact on PD muscle activity (Brookham et al, 2010; Ebaugh et al, 2005).

Our findings shed light on the importance of sitting posture and arm flexion angle on shoulder ROM as well as on scapular and shoulder muscle activities. Clinicians often disregard sitting posture when recuperating shoulder ROM. However, slouched sitting restricts scapular movement and arm ROM and may lead to shoulder impingement or forward head posture (Kanlayanaphotporn, 2014). Furthermore, regardless of the arm elevation angle, slouched sitting increases UT muscle activity and possibly produces potential muscle fatigue (Ludewig and cook, 2000; Malmströmm et al, 2015). Educational instruction for normal alignment with appropriate sitting posture for sedentary workers and students may be helpful in the prevention of muscle fatigue and of the disorders described above. When treating patients with neurologic disorders, such as stroke or Parkinson's disease, appropriate instruction will potentially enhance functional daily activities by restoring correct sitting posture (Pascarelli et al, 2001).

A limitation of this study was the participant group: the subjects were young adults without any musculoskeletal disorders, such as shoulder impingements or upper-cross syndrome. In addition, surface EMG has the inherent disadvantage of measuring only superficial, and not deep, muscle activities. We performed EMG during shoulder flexion in the scapular plane only without internal or external rotation; EMG of the more common upper-extremity activities in slouched posture should therefore be explored in the future. Other scapular stabilization muscles, such as the serratus anterior, middle and lower trapezius, rhomboids, and rotator cuff muscles, also need to be further studied during slouched sitting.

Conclusion

This study compares the effects of sitting postures and shoulder flexion angles on shoulder muscle activities based on genders. The results demonstrated that active ROMs of the shoulder external rotation and the flexion in the scapular plane decreased from the upright posture to the maximum slouched posture. All muscles showed the highest EMG activities at 120° shoulder flexion with the maximum slouched posture and did not show the gender differences. This study suggested that sitting posture might play an important role for the movements in scapular and glenohumeral joints; therefore, upright sitting posture is required during treatment for upper extremities.

References

Alizadehkhaiyat O, Hawkes DH, Kemp GJ, et al. Electromyographic analysis of shoulder girdle muscles during common internal rotation exercises. Int J Sports Phys Ther. 2015;10(5):645-654.

Brookham RL, Wong JM, Dickerson CR. Upper limb posture and submaximal hand tasks influence shoulder muscle activity. Int J Ind Ergon. 2010;40(3):337-344.

Bullock MP, Foster NE, Wright CC. Shoulder impingement: The effect of sitting posture on shoulder pain and range of motion. Man Ther. 2005;10(1):28-37.

Caneiro JP, O'Sullivan P, Burnett A, et al. The influence of different sitting postures on head/neck posture and muscle activity. Man Ther. 2010;15(1):54-60 https://doi.org/10.1016/j.math.2009.06.002

Culham E, Peat M. Functional Anatomy of the Shoulder Complex. J Orthop Sport Phys Ther. 1993;18(1):342-350.

Ebaugh DD, McClure PW, Karduna AR. Three-dimensional scapulothoracic motion during active and passive arm elevation. Clin Biomech(Bristol. Avon). 2005;20(7):700-709.

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

Finley MA, Lee RY. Effect of sitting posture on 3-dimensional scapular kinematics measured by skin-mounted electromagnetic tracking sensors. Arch Phys Med Rehabil. 2003;84(4):563-568.

Kanlayanaphotporn R. Changes in sitting posture affect shoulder range of motion. J Bodyw Mov Ther. 2014;18(2):239-243. https://doi.org/10.1016/j.jbmt.2013.09.008

Kebaetse M, McClure P, Pratt NA. Thoracic position effect on shoulder range of motion strength, and three-dimensional scapular kinematics. Arch Phys Med Rehabil. 1999;80(8):945-950.

Lee ST, Moon J, Lee SH, et al. Changes in activation of serratus anterior, trapezius and latissimus dorsi with slouched posture. Ann Rehabil Med. 2016;40(2):318-325. https://doi.org/10.5535/arm.2016.40.2.318

Liu J, Hughes RE, Smutz WP, et al. Roles of deltoid and rotator cuff muscles in shoulder elevation. Clin Biomech (Bristol. Avon). 1997;12(1):32-38. https://doi.org/10.1016/S0268-0033(96)00047-2.

Ludewig PM, Cook TM. Alterations in shoulder kinematics and associated muscle activity in people with symptoms of shoulder impingement. Phys Ther. 2000;80(3):276-291. https://doi.org/10.2519/jospt.1993.17.5.212.

Ludewig PM, Cook TM, Nawoczenski DA. Three-dimensional scapular orientation and muscle activity at selected positions of humeral elevation. J Orthop Sports Phys Ther. 1996;24(2):57-65.

Ludewig PM, Reynolds JF. The Association of Scapular Kinematics and Glenohumeral Joint Pathologies. J Orthop Sport Phys Ther. 2009; 39(2):90-104. https://doi.org/10.2519/jospt.2009.2808

Malmströmm EM, Olsson J, Baldetorp J, et al. A slouched body posture decreases arm mobility and changes muscle recruitment in the neck and shoulder region. Eur J Appl Physiol. 2015; 115(12):2491-2503. https://doi.org/10.1007/s00421-015-3257-y

McLean L. The effect of postural correction on muscle activation amplitudes recorded from the cervicobrachial region. J Electromyogr Kinesiol. 2005;15(6):527-535.

Nagai K, Tateuchi H, Takashima S, et al. Effects of trunk rotation on scapular kinematics and muscle activity during humeral elevation. J Electromyogr Kinesiol. 2013;23(3):679-687. https://doi.org/10.1016/j.jelekin.2013;01.012

Nairn BC, Chisholm SR, Drake JD. What is slumped sitting? A kinematic and electromyographical evaluation. Man Ther. 2013;18(6):498-505. https://doi.org/10.1016/j.math.2013.03.003

Neumann DA. Kinesiology of the Musculoskeletal System: Foundations for rehabilitation. 3rd ed. St. Louis, Missouri, Elsevier Inc., 2017:149-151.

Nie HL, Arendt-Nielsen L, Kawczynski A, et al. Gender effects on trapezius surface EMG during delayed onset muscle soreness due to eccentric shoulder exercise. J Electromyogr Kinesiol. 2007; 17(4):401-409.

O'Sullivan PB, Dankaerts W, Burnett AF, et al. Effect of different upright sitting postures on spinal-pelvic curvature and trunk muscle activation in a pain-free population. Spine (Phila Pa 1976). 2006;31(19):(E)707-712.

Pascarelli EF, Hsu YP. Understanding Work-Related Upper Extremity Disorders: Clinical Findings in 485 Computer Users, Musicians, and Others. J Occup Rehabil. 2001;11(1):1-21.

Schüldt K, Ekholm J, Harms-Ringdahl K, et al. Effects of changes in sitting work posture on static neck and shoulder muscle activity. Ergonomics. 1986; 29(12):1525-1537.

Sciascia A, Kuschinsky N, Nitz AJ, et al. Electromyographical comparison of four common shoulder exercises in unstable and stable shoulders. Rehabil Res Pract. 2012;2012:783824. https://doi.org/10.1155/2012/783824

Uga D, Endo Y, Nakazwa R, et al. Electromyographic analysis of the infraspinatus and scapular stabilizing muscles during isometric shoulder external rotation at various shoulder elevation angles. J Phys Ther Sci. 2016;28(1):154-158. https://doi.org/10.1589/jpts.28.154

This article was received January 3, 2018, was reviewed January 3, 2018, and was accepted February 5, 2018.