Journal of Engineering and Applied Sciences 13 (Special Issue 2): 2909-2914, 2018
ISSN: 1816-949X

The Comparison of the Upper Limb Muscle Activity According to Shoulder Angle with the Push up Plus Exercise

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Abstract: The purpose of this study is investigating the difference in muscular activity of shoulder muscle depending on the shoulder angle and height of pelvic limb. The subject consisted of 20 healthy adult male and 10 healthy female excluding the ones with shoulder-related injury. The shoulder angle was set to 70, 90 and 110° according to the height of legs and the height of legs was set to 0, 50 and 80 cm. The experiment was conducted in random order. The statistical analysis used repeated ANOVA. According to the experiment result, the muscular activity of serratus anterior muscle, pectoralis major muscle and upper trapezuius muscle increased as shoulder angle increased. According to the result of this study, serratus anterior muscle, pectoralis major muscle and upper trapezuius muscle showed significant difference in muscular activity between 70° and 90° and between 70° and 110° but 90° and 110° did not show significant difference. Therefore, performing push-up plus by adjusting the height of the leg to healthy adults with weak shoulder muscle was effective.

Key words: Push up plus, shoulder angle, lower limb height, muscle activity, adjusting, muscle

INTRODUCTION

People experience much discomfort of diseases related with a shoulder for all ages. The shoulder joint is multi-axial and is composed of a complex structure and is dependent on muscles and ligaments than bones for supporting, stability and intactness of a shoulder as a spheroid articulation. The contact surface of spheroid articulation is low and has a narrow stability and those who have a functional problems caused by unstable shoulder joint suffer from the spheroid articulation (Newmann, 2010). The shoulder joint is working in association with the movement of the shoulder blades to produce a large range of motion of the shoulder, the movement of the shoulder joint is a stable movement of the shoulder bone because action needs to be united with the shoulder bones (Kim and Kim, 2013). The exercise called push-up plus to strengthen the muscles around the shoulder for the shoulder bone to make a stable movement. The purpose of the push-up plus exercise is to stabilize the shoulder joint and this push-up plus does not bend the elbow joint compare with the ordinary push-up and add the motion of moving in or out the shoulder bone (Kibler *et al*., 2012). Push-up plus exercise is developed by the representative push-up exercise among the closed chain motion (Batbayar *et al*., 2015). Therefore, The previous study recommended the push-up plus exercise as an effective closed chain motion to strengthen the serratus anterior muscle to stabilize the shoulder bone (Newmann, 2010). The closed chain movement is to stabilize the joint and the push-up plus exercise combining push-up with closed chain movement is helpful to stabilize the muscles on the shoulder bones (Cho *et al*., 2014). In addition, the push-up plus exercise influences on rotator cuff of the shoulder joint and is helpful to stabilize the motion of the shoulder joint (Park and Yoo, 2011). Push-up plus exercise is effective for stabilizing the spine by strengthening the abdomen as well as the shoulder (Kim and Kim, 2013). Also, shoulder joint changed by abduction angle of scapular (Hong *et al*., 2015). Winging scapular is caused by the weakening of the muscle around the shoulder bone (Choi and Lee, 2013). Main problem of winging scapular is the weakened serratus anterior muscle and trapezius muscle (Araujo *et al*., 2011). Strengthening serratus anterior muscle in doing push-up exercise is to prevent winging scapular and to prevent leaning forward of the shoulder bone (Park and Yoo, 2011) and to increase the muscle activity of serratus anterior muscle by applying push-up plus exercise for the ordinary adults with problems of functioning or distortion of shoulder

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bones (Kibler *et al*., 2012). To increase the additional muscle activity when doing push-up plus exercise on the stable supporting surface and on the unstable surface, the research showed that increasing the muscle activity of serratus anterior muscle on the unstable supporting surface is more effective (Park *et al*., 2013). In addition when lifting the leg higher in a push-up position, the muscle activity of the shoulder muscle was increased (Jung *et al*., 2012). Lifting the leg on a higher position is helpful to increase the proprioceptive sense of arms and the muscle activity of serratus anterior muscle by loading the weight to the arms (Yoo, 2014). Push-up plus exercise is effective to the female and male adults that the articulation of the shoulder bone is not correct (Dannelly, 2011). On the basis of the above previous study, height adjustment of legs in doing push-up plus exercise was combined and the changes of angles of arms have been added for accurate measure. By changing the angle of the shoulders and the height of legs following the unstable surface of arms, how push-up plus exercise suggests the strengthening the muscle of arms and the effective angle of arms and the height of legs in trapezius muscle, serratus anterior muscle and pectoralis major muscle for the adults having problems of unstable shoulder joint by weakening the muscle around the shoulder and the problems of unstable articulation of the shoulder bone and informing push-up plus exercise on the effect of stabilization of the shoulder bone.

MATERIALS AND METHODS

This study has been conducted, since, June 21st 2015 under the approval of the ethics committee. The participants are a healthy 20 males and 10 females of a student of S university with no previous damage of the shoulder joint and elbow joint. Before conducting the experiments, the agreements from the participants have been obtained in advance. The method of exercise was informed to the participants by the previous practice and the features of the participants are shown in Table 1. To add the unstable supporting surface, a balance pad (TOCU, GTG 400200, Germany, 2010) was used and to see the muscle activity of the muscles of shoulder (serratus anterior muscle, trapezius muscle and pectoralis major muscle), EMG (Zero WIRE EMG, EMG OQUS100, Italy, 2009) was used in this experiment. The EMG mounting position of each muscle is shown in Table 2. Orthopedic physical therapy table (Ntech, GTR-2000, Korea, 2011) was used, to adjust the alignment of the body of the participant and to confirm the height of the legs is increased as the figure, a digital protractor (Digital absolute+axis, 12-1027, USA, 2012) for the angle of the shoulder was used (Fig. 1). Before the experiment day, the participants confirm if the motion is correct by doing push-up plus exercise. Experiments were conducted at random and one motion was performed per day. The pad balance was used to provide the unstable supporting surface to all participants and the angle of the shoulder was measured by using a digital protractor. In addition, a shoulder, a coxal articulation and a malleolus were aligned straight in line. The angle of the shoulder for the first push-up plus motion was set as 70° (Fig. 2) and the angle of the shoulder for the second push-up plus motion was set as 90° (Fig. 3) and the angle of the shoulder for the third push-up plus motion was set as 110° (Fig. 4). The

Table 1: General characteristics of the participants (n = 30)

Veriables	Male (n = 20)	Female (n = 10)
Age	19.55±1.70	19.40±0.84
Height (cm)	176.2±6.350	160.1±6.020
Weight (kg)	72.9±11.96	58.2±7.450

Mean±SD

Table 2: The EMG mounting position of each muscle

Muscles	Pad attaching position
Upper trapezius	C7 SP between the center of the scapula and acromion
Pectoralis major	Under the direction of the diagonal clavicle 2 cm
Serratus anterior	Latissimus dorsi on the bottom edge inside the border scapula

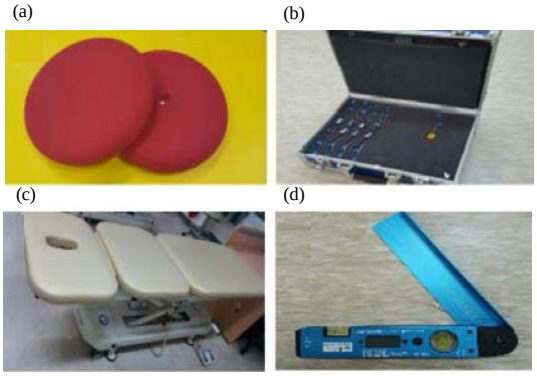

Fig. 1: a) Balance pad; b) Surface EMG; c) Orthopedic physical therapy table and d) Digital protractor

Fig. 2: Push up plus exercise of shoulder angle 70°

Fig. 3: Push up plus exercise of shoulder angle 90°

Fig. 4: Push up plus exercise of shoulder angle 110°

height of a hip and legs from the ground for each exercise motion with 70° was 45 cm and the height of a foot is 0 cm. The height of a hip with 90° of a ground is 45 cm and the height of a foot was 50 cm and the height of a hip from a ground with 110° is 65 cm and the height of a foot was 80 cm. The average value is calculated considering the height of participants with a different body structure and the angle of the shoulder is the same and the shoulder, coxal articulation and malleolus were to be aligned in line. The neck was to bend when performing every bend. To measure the speed of push-up plus exercise, metronome was used (BPM 40, Beats 4). The repeated ANOVA was conducted to compare the average value of the muscle activity according to the angle and the angle of arms were classified as 70°, 90° and 110° in this study. In addition, the analysis of the research result was statistically conducted by using SPSS/PC Ver. 22.0 for windows program (IBM SPSS Statistics 22). The muscle activity showed %MVIC and the statistical significant level was established as $p<0.05$.

RESULTS AND DISCUSSION

Table 3 shows the comparison of muscle activity among serratus anterior muscle, trapezius muscle and pectoralis major muscle according to the angles. The muscle activity of trapezius muscle showed meaningful

Table 3: Comparison of changing shoulder angle according to the muscle activity in upper trapezius, serratus anterior, pectoralis major. unit: %MVC

Angle	Upper trapezius	Pectoralis major	Serratus anterior
70°	18.54±4.30	18.55±5.44	26.07±8.75
90°	101.95±4.13	101.90±3.39	101.75±3.74
110°	102.79±4.44	103.46±5.70	109.14±36.70
F-value	0.000$^{\tau}$	0.000$^{\tau}$	0.000$^{\tau}$

Mean±SD, $^{\tau}$ $p<0.05$

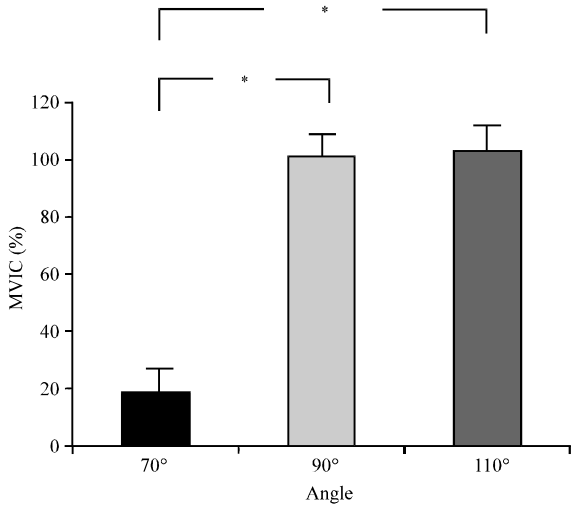

Fig. 5: Comparison of upper trapezius muscle activity according to the shoulder angle; $^{\tau}p<0.05$ (%MVIC)

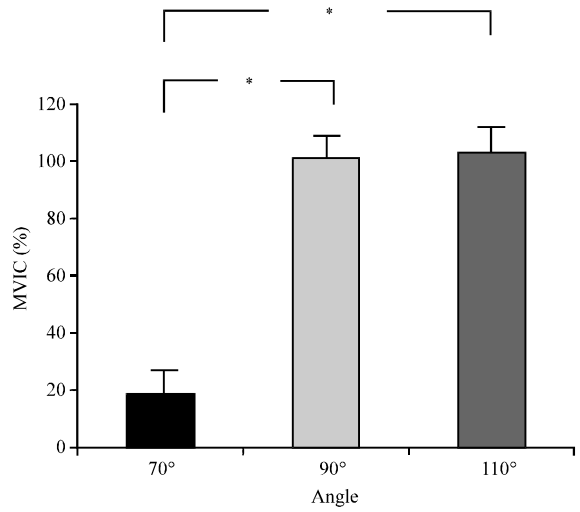

Fig. 6: Comparison of serratus anterior muscle activity according to the shoulder angle; $^{\tau}p<0.05$ (%MVIC)

difference when comparing the angle between 70° and 90° and between 70° and 110° (Fig. 5). When comparing the muscle activity of serratus anterior muscle, meaningful difference was shown in the angle between 70° and 90° and between 70° and 110° (Fig. 6). In addition when

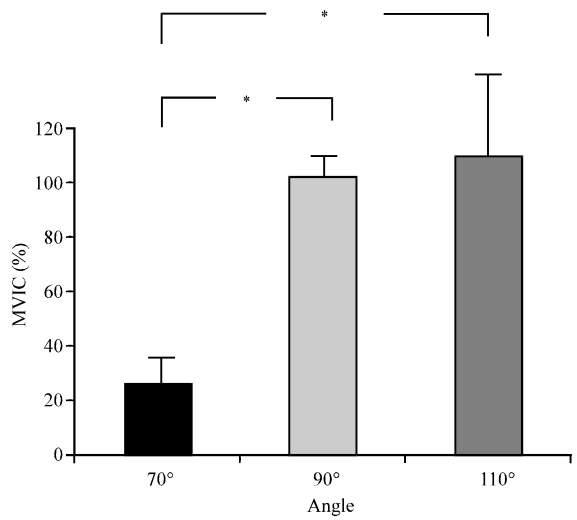

Fig. 7: Comparison of pectoralis major muscle activity according to the shoulder angle; *p<0.05 (%MVIC)

comparing the muscle activity of pectoralis major muscle, meaningful difference was shown in the angle between 70° and 90° and between 70° and 110° (Fig. 7).

This study is to review how the muscle activity of trapezius muscle, serratus anterior muscle and pectoralis major muscle are influenced by the height of legs as the angle of the shoulder is increased. The studies on push-up plus regarding knees or using a gym ball were abundant, however, the studies on the muscle activity of push-up plus exercise around the shoulder adjusting the angle of the shoulder or the height of the legs. In this study, a balance pad was used and push-up plus exercise was performed comparing the muscle activity of trapezius muscle, serratus anterior muscle and pectoralis major muscle. One of the previous studies showed that performing push-up plus on the unstable supporting surface is more effective than on the stable supporting surface (Kim and Lee, 2012). The unstable supporting surface was added to motivate the muscle activity. The muscles strengthened in the previous push-up plus exercise were trapezius muscle, serratus anterior muscle and pectoralis major muscle and winging scapular might be caused when those muscles are weakened (Yoo, 2014). The reason that trapezius muscle, pectoralis major muscle and serratus anterior muscle was decided is because trapezius muscle is related with the muscle above the shoulder bone and as seen in the study, the shoulder bone is turned upward when the shoulder was bent. Therefore, as the angle of the shoulder in trapezius muscle, the muscle activity in performing push-up plus is influenced. Pectoralis major muscle helps to concentrate on the shoulder and hold out the shoulder bone and the shape of the shoulder became round (Lee *et al*., 2011). It shows the concentrating motion. As the bending angle of the shoulder in pectoralis major muscle is increased, the concentrating motion is shown and the muscle activity on pectoralis major muscle is larger. Serratus anterior muscle is a muscle related with a shoulder and push-up plus motion to repeat holding out and letting in of the shoulder bone and because the motion of serratus anterior muscle is related with the shoulder bone, the muscle activity of trapezius muscle, pectoralis major muscle and serratus anterior muscle is influenced in performing push-up plus. Twenty males and ten females were participated in this study. The proportion of males is larger than that of females. The exercise shown in this study is required for the muscle and so the muscle condition of males can be more reviewed and in case of females, performing the exercise relatively in an inaccurate way and so the proportion of males became larger. In addition, the muscle activity around the shoulder bone by adjusting the height of legs is reviewed and specifically the bending angle of the shoulder to raise legs is set to 70°, 90° and 110°. The angle of 70° is the basic posture of this study for the basic push-up exercise. The angle 90° makes the body and the ground in line and proper weight around the shoulder is given. To provide the 20° of regular distinctiveness, the angle 110° was applied. The angle of the shoulder is set as 70°, 90° and 110° to all participants and made the bones of the arm, head, coxal articulation and malleolus were aligned in line. Participants were selected at random among people who have not been damaged the shoulder and so, the heights of the participants were various and the experiment was conducted according to the height of the legs by the differentiation of the length of arms and legs. The height of legs were set as 0, 30 and 60 cm each to perform push-up and a box was used for the 30 cm and Bobath table was used for 60 cm. As a result, the meaningful difference in muscle activity of serratus anterior muscle and deltoid muscle was shown. Therefore, the result of this study on each muscle activity is influenced by the bending angle of the shoulder to 70°, 90° and 110° and adjusting the height of legs also influence the muscle activity of serratus anterior muscle. The previous study measured the muscle activity of the right shoulder in performing push-up plus and reviewed the difference of muscle activity when lifting the leg on the same side and the opposite side (Cho, 2015). As a result when lifting the leg on the opposite side, meaningful difference of muscle activity in trapezius muscle, serratus anterior muscle and pectoralis major muscle was shown. Therefore, the result of this study, meaningful difference in three muscles by performing push-up plus exercise with lifting the legs is shown. In

addition, if a leg lifts, the weight is loaded to the shoulder and the gravity is moved to the front and so, the muscle activity is increased. The previous study showed meaningful difference in serratus anterior muscle and pectoralis major muscle is shown in the study on muscle activity of the shoulder in performing push-up plus exercise by bending or extending a neck and the muscle activity on pectoralis major muscle when bending a neck was high (Cho, 2015). This can be explained that the meaningful difference on muscle activity of pectoralis major muscle with bending a neck. The meaningful difference in the angle of 70° and 90° and 70° and 110° was shown in this study. However, meaningful difference in the angle of 90° and 110° was not found. The height of the leg with the angle of 70° was 0 cm because the leg is not lifted and the height is 50 cm in the angle of 90° and the height of the leg with the angle of 110° was 80 cm. The difference of the average height in the angle of 70° and 90° was 50 cm and that of the angle of 70° and 110° was 80 cm. However, the difference of the average height of the leg in the angle of 90° and 110° was 30 cm. Even if the angle of 70° and the other two angles shows a big difference but the difference in the angle of 90° and 110° was small compared with the angle of 70°. Through this study, the increase of shoulder bending angle, height of the leg, weight of a shoulder in performing push-up plus have the same meaning. The reason that the weight of a shoulder increases is because the body and the ground is parallel. However in the angle of 110°, the angle of the ground and the body became larger than 0° and the gravity of the center is moved in front and the weight of loading influences on the muscle. Therefore, the muscle activity of all shoulder muscles in the shoulder angle of 110° showed the highest condition.

CONCLUSION

The purpose of this study is to confirm the muscle activity of the upper body by the height of the leg and the bending angle from the ground in performing push-up plus exercise and to confirm the muscle activity of trapezius muscle, serratus anterior muscle and pectoralis major muscle related with the muscle around the shoulder bone by each angle and the height of the leg. When the height of the leg by increasing the angle of muscle is increased, the muscle activity (%MVIC) of all muscles was increased. The three muscles, trapezius muscle, serratus anterior muscle and pectoralis major muscle showed a meaningful difference in the angle between 70° and 90° and between 70°and 110° Therefore, performing push-up plus by adjusting the height of the leg to healthy adults with weak shoulder muscle was effective.

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