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Effect of the Push-up Plus (PUP) Exercise at Different Shoulder Rotation Angles on Shoulder Muscle Activities

Sung-Hak Cho, MS, PT[1)], Il-Hun Baek, MS, PT[2)*], Ju Young Cheon[2)], Min Jung Cho[2)], Mi Young Choi[2)], Da Hye Jung[2)]

[1)] *Department of Physical Therapy, Catholic University of Pusan, Republic of Korea*
[2)] *Department of Physical Therapy, Dong-Eui Institute of Technology: 54 Yangji-ro, Busanjin-gu, Busan 614-715, Republic of Korea*

Abstract. [Purpose] Although the Push-Up Plus is a useful exercise method for shoulder stabilization, few studies have examined its effects at different angles of shoulder rotation. Therefore, the present study investigated the most effective exercise method for shoulder stabilization by analyzing muscle activities of the rotator cuff muscles at different angles of shoulder rotation. [Subjects] Fifteen healthy university students in their 20s were the subjects of this study. [Methods] Changes in muscle EMG related to shoulder stabilization were analyzed by performing the Push-Up Plus in shoulder positions of neutral, internal and external rotation. [Results] The highest muscle activity was found in external rotation, and in internal rotation the pectoralis major and levator scapula showed significantly lower activities than the other positions. [Conclusion] Selectively changing the rotation angle of the shoulder for different purposes of the shoulder exercise would be an effective exercise method.
Key words: Shoulder, Stabilization, Rotation

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INTRODUCTION

The rotator cuff is the most important muscle group for shoulder stabilization. In shoulder stabilization, the rotator cuff controls many active joint movements occurring in the glenohumeral joint. The rotator cuff has three main functions: it rotates the humeral head; it presses the humeral head down, stabilizing the head in the joint pit; and, it stabilizes the shoulder muscles by maintaining proper balance when the other big muscles, that cross shoulder joint contract[1)]. The serratus anterior (SA) is also considered to be an important shoulder muscle stabilization. Proper activity of the SA is important for maintaining normal scapulohumeral rhythm during arm raises. SA holds the scapula to the thorax when the humerus is raised in flexion and abduction. It also prevents winging of the scapula and helps the scapula to tilt posterior in upward rotation. SA shows abnormal muscle activity in various kinds of pathological condition of the shoulder muscle[2)]. It plays an important role in the scapula stabilization and strengthening of SA significantly contributes to shoulder stabilization[3)].

Recently, the Push-Up Plus (PUP) exercise has been widely used as an exercise method to strengthen the rotator cuff. PUP is an effective exercise method that decreases action of the trapezius muscle and increases activity of SA. Among PUP exercises, it is known that exercise on an unstable base of support has the most effect[4, 5)]. Exercise methods for shoulder stabilization, to improve rehabilitation of patients with shoulder damage, have continuously improved with time. However, there have been few studies of the effects of PUP exercise at different shoulder rotation angles. The muscles of the rotator cuff change their length with rotation of the shoulder joint strength, and muscle tension changes with length. Thus, strength will also change with shoulder rotation. Therefore, the present study investigated most effective exercise method for shoulder stabilization by analyzing the muscle activities of the rotator cuff at various shoulder rotation angles.

SUBJECTS AND METHODS

The subjects of this study were 15 healthy D university students, in their 20s (5 males, 10 females), who had no restriction on exercise, and no shoulder pain within the previous 3 months. None of them had a history of shoulder surgery. Written informed consent was received from each subject. This study was approved by the Ethics Committee of the Catholic University of Pusan.

To measure muscle activity, a surface electromyography system (Noraxon, USA) was used. Electrodes were attached to the upper trapezius (UT), lower trapezius (LT), levator scapula (LS), supra spinatus (SS), infra spinatus (IS), posterior deltoid (PD), serratus anterior (SA) and pectoralis major

*Corresponding author. Il-Hun Baek (E-mail: b101h@naver.com)

(PM) Table 2[6, 7]. The muscle activities of these 8 muscles at three different shoulder rotation angles were measured during PUP on an unstable surface provided by a sling. The subjects practiced for 5 minutes before the measurements to learn the scapula protraction at the different rotation angles, and subjects were instructed not to raise their thoracic vertebrae too much in reaction to the protraction. All exercises were performed in the quadruped position, with the hip and shoulder joints at 90-degree angles and the sling suspending the hands 5 cm above the floor at the start of the PUP exercises.

In the present study, the posion with both thumbs up and the back of the hands facing outwards was called the neutral rotation (NR) position. The position with both thumbs facing each other, at a 90° rotation from the NR position was called the internal rotation (IR) position. The position with both thumbs facing outwards, a 60° rotation from the NR position, was called the external rotation (ER) position. Since muscle activity can be changed by the order of measurement, measurements were taken in the following order: NR, IR and ER; IR, ER and NR; ER, NR, IR. The average values of the 3 measurements were used. Three minutes of break time were provided between each measurement. To avoid any changes in positions due to movement of the head, or the position of the trunk, a posture correction stick was used.

To prevent subjects from flexing or extending of their neck during the measurements, they were told to pull in their chin, and measurement, each angle was controlled to touch the stick with the back of their heads to maintain the alignment of their back and hips. After the initial by putting some stickers on the floor (Fig. 1). For normalization of the EMG, the muscle activity of each muscle was measured in maximal voluntary isometric contraction (MVC) in the manual muscle testing position.

SPSS 18.0 was used for statistical analysis in the present study. To compare muscle activities of each muscle among the 3 different positions, two-way repeated ANOVA was

Table 1. Characteristics of the healthy subjects (N=15)

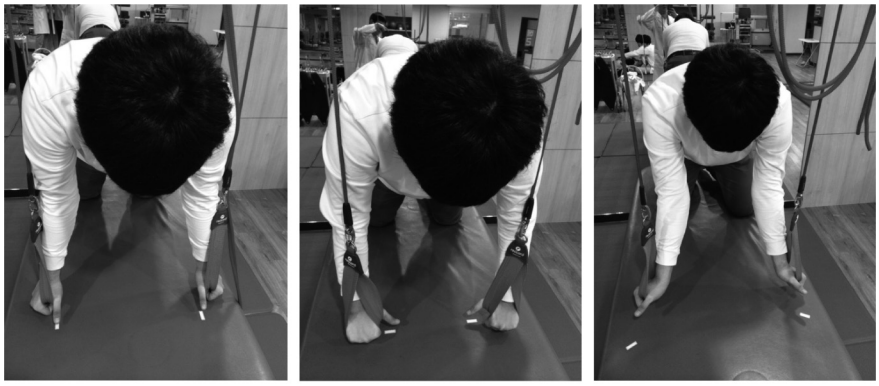
Description	
Gender (M/F)	5/10
Age (y)	22.1 (2.9)
Height (cm)	165.6 (4.3)
Weight (kg)	60.1 (11.1)

Values are Means ± SD

Table 2. Surface electrode attachment sites

Muscles	Surface electrode attachment sites
UT	Between spinous process of 7th cervical vertebra and acromion
LT	2 cm away from spinous process of the inferior angle level
LS	Btween sternocleidomastoid and upper trapezius muscle
SS	Attached to the spinous process of the scapula after locating the external distal part of the spinous process with tactile perception
IS	After locating the spinous process with tactile perception, the electrode was attached to the lower spinous process 4 cm from the lateral margin in parallel
PD	Lower edge of scapular spine
SA	Front part of latissimus dorsi on center armpit line at the 5th, 6th rib bone level
PM	2 cm proximally from armpit crease

Upper Trapezius (UT), Lower Trapezius (LT), Levator Scapula (LS), SupraSpinatus (SS), InfraSpinatus (IS), Deltoid Posterior (PD), Serratus Anterior (SA), Pectoralis Major (PM)



Neutral Rotation Internal Rotation External Rotation

Fig. 1. Push up plus exercise using different rotation angles

used, and one-way ANOVA as a post hoc test. Statistical significance was accepted for values of $p<0.05$.

RESULTS

The general characteristics of the subjects are presented in Table 1.

The shoulder muscle activities of UT, LT and PD showed no significant differences among the shoulder positions ($p>0.05$); however, there were significant differences in LS, SS, IS, SA, and PM ($p<0.05$) (Table 3).

DISCUSSION

According to the results of the present study, the highest muscle activity was found in ER overall. Compared to the neutral position, PUP with ER showed significantly higher activities of SS, IS, SA, and PM. Through its structural characteristics, the rotator cuff provides comprehensive force to the glenohumeral joint and act as a static and dynamic stabilizer[8]. The SS, IS, and SA play important roles in shoulder stabilization[1, 3], and PM provides a role as a dynamic stabilizer during arm movement. SA is a direct muscle that holds the scapula to the trunk. It provides a role as a lever, controls abduction and upward rotation of the scapula and keep the scapula flat to costal angle[9]. When the SA is weakened, winging of the scapula occurs, and to compensate for this, excessive work of UT occurs, resulting in abnormal the scapula movement[10]. Many researchers are studying stabilization of the scapula to find ways of stabilizing the upper extremity, and they are looking for ways to selectively strengthen the rotator cuff and SA. In the present study, significant increases in SS, IS, PM, and SA activities were found, compared to PUP exercise in the NR and IR positions when PUP was performed with external rotation of the shoulder. PUP exercise with external rotation showed the highest activity in almost all the muscles.

Unlike the normal movement of the shoulder, when a subject has pain or problems with the movement pattern, the strategy for shoulder stabilization needs to be different from that for people with no problem or no pain. Sahrmann[10] defined as "movement impairment syndrome", and explained that it can result in pain at certain sites due to abnormal movement of the scapula and upper arms. It can also result in increase or decrease of scope of joint movement, stress in a certain direction or compensation movement in a certain direction due to directional susceptibility to movement, and decrease of muscle strength. Mottram[11] noted that proper force couple should be recovered through appropriate isometric exercise which provides the muscle stability necessary to recover from these abnormal scapula movements. Ludewig PM et al.[3] concluded that the push-up plus is an ideal exercise for people with excessive UT muscle activity or people with UT and SA imbalance and this has been confirmed in many studies[12, 13].

The present study observed the muscle activities of different shoulder rotation angles during PUP, and PUP with IR showed significantly lower PM and LS when activities than PUP with NR or ER. Excessive activity of PM and LS can result in imbalance in the neck and shoulders. Chaitow[14] defined this as upper crossed syndrome (UCS) nothing that while patients with UCS have overly tensioned PM, UT and LS, they have weakened deep cervical flexors, LT and SA. Despite the low PM and LS activities observed in PUP with IR, higher LT and SA activities were found than in PUP with NR. Thus, PUP with IR can be recommended as a selective exercise method for patients with UCS, which results from excessive PM and LS, for in strengthening the rotator cuff and SA while minimizing PM and LS activities.

The present study had some limitations. There were only 15 subjects of the study, and they were healthy subjects in their 20s with no shoulder pain. So it is difficult to generalize the results to those who have shoulder disease, UCS or for elderly people. In addition, in this we used surface electromyography, therefore, it was not possible to analyze the muscle activities of the teres minor or subscapularis. Therefore, in further studies, it will be necessary to address these limitations.

The present study investigated out the most efficient shoulder stabilization exercise method by observing the activities of muscles around shoulder during PUP with different rotation angles of the shoulder. According to the results of the present study, PUP with ER is the most effective stabilization exercise, since it showed significantly higher activities of SS, IS, SA and PM than the other positions. In addition, PUP with IR was found to be the exercise method that can selectively strengthen SS, IS and LT while minimizing the activities of PM and LS. Therefore, selecting different rotation angles of the shoulder for different purpose of shoulder exercise is to be an effective exercise method.

Table 3. Shoulder muscle activities (N=15)

	Neutral rotation	Internal rotation	External rotation
UT	10.35±2.93	9.89±5.02	10.44±4.97
LT	6.98±2.44	7.18±5.12	7.87±4.71
LS*	8.99±4.39[b]	7.57±4.49[a]	8.67±4.34[b]
SS*	3.86±2.15[a]	4.47±2.66[a]	5.23±3.21[b]
IS*	6.39±5.49[a]	6.63±6.53[a]	9.07±7.71[b]
PD	7.03±9.23	7.30±7.41	7.66±5.21
SA*	18.30±11.06[a]	22.95±17.45[a]	27.89±20.03[b]
PM*	28.66±16.34[b]	24.89±17.23[a]	36.64±21.39[c]

Upper Trapezius (UT), Lower Trapezius (LT), Levator Scapula (LS), SupraSpinatus (SS), InfraSpinatus (IS), Deltoid Posterior (PD), Serratus Anterior (SA), Pectoralis Major (PM)
Values are Means ± SD (a<b<c, * $p<0.05$, significant difference between rotation positions)

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