



Original Article

The effect of an active vibration stimulus according to different shoulder joint angles on functional reach and stability of the shoulder joint

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Abstract. [Purpose] The purpose of this study was to analyze the effect of an active vibration stimulus exercise according to shoulder joint angles on functional reach and stability of the shoulder joint. [Subjects and Methods] Thirty healthy male students participated in this study. Upper limb length of each subject was measured to obtain normalized measurement values. The exercise groups were as follows: group I (n=10, shoulder joint angle of 90°), group II (n=10, shoulder joint angle of 130°), and group III (n=10, shoulder joint angle of 180°). After warm-up, an active vibration stimulus was applied to the subjects with a Flexi-Bar. The Functional Reach Test and Y-balance test were conducted for measurement of shoulder stability. [Results] Analysis of covariance was conducted with values before the intervention as covariates to analyze the differences among the groups in the two tests. There were significant differences among the groups. According to Bonferroni post hoc comparison, group I showed greater improvement than group III in the Functional Reach Test, and group II showed greater improvement than group I and group III in the Y-balance test. [Conclusion] The effect of the exercise with different shoulder joint angles revealed that the shoulder joint has a certain effective joint angle for its functionality and stability. In addition, application of an active vibration stimulus with a Flexi-Bar can be a very effective tool for improvement of functionality and stability of the shoulder joint.

Key words: Active vibration stimulus, Flexi-Bar, Shoulder joint angle

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INTRODUCTION

Poor posture in students in the growth period causes chronic pain in the neck and shoulder joint and is related to trunk postures¹⁾. Biomechanical alterations in the scapula affect muscle activity²⁾, causing an abnormal activity pattern in the shoulder complex followed by imbalance of surrounding muscles^{3,4)}. For treatment of imbalance of the surrounding muscles, the scapula should be returned to its ideal position by exercising the muscles that contribute to scapular stability⁵⁾. Ideal scapular alignment stabilizes the glenohumeral joints and synergizes humerus movement⁶⁾.

The serratus anterior, upper trapezius, lower trapezius, and rotator cuff, as scapular stabilizers, provide stability through upward rotation of the scapula in flexion and abduction of the upper extremities⁷⁾. Upward rotation of the scapula plays an important role in upper extremity movement. Patients with scapula joint pain showed decreased serratus anterior muscle activity and increased upper trapezius muscle activity⁸⁾. This causes a compensatory response in the form of abnormal upward rotation of the scapula, inducing pain and subacromial impingement^{3,4,9)}.

Therefore, scapular lateral movement while raising the upper extremity is important for maintenance of the ideal scapulothoracic rhythm¹⁰⁾. Wickham et al. reported the angle with the highest muscle activity among different angles of shoulder

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abduction¹¹). Reinold et al. reported the rotator cuff and deltoid activation angles in accordance with different angles of shoulder joint¹²). Therefore, shoulder muscle activity is affected by the angles of flexion and abduction.

It is important to understand the relationship between muscle strength and joint angle to conduct exercise for enhancement of muscle activity effectively. A change in joint angle alters the length of the moment arm and upper limb muscles, therefore causing a change in muscle contraction¹³). Each joint of the body has a specific joint angle with optimal mechanical benefit¹⁴), and each muscle has a length that can trigger the greatest strength at that angle¹⁵).

There are two types of shoulder joint stability exercise: open and closed kinetic chain exercises. In open kinetic chain exercises in particular the distal portion of the limb moves while the proximal portion is fixed. These exercises are suitable for patients with a limited range of motion for muscle strengthening, as they increase acceleration and facilitate functional activities¹⁶). Recently, there have been studies on a combination of vibration stimulus and open kinetic chain exercise^{17, 18}). The Flexi-Bar, a 152-cm-long elastic bar, is used as a training tool that provides a vibration stimulus. Shaking the bar actively delivers a vibration stimulus of 5 Hz throughout the body and facilitates muscle activity of the limbs and trunk¹⁸). In addition, it has been reported that the vibration stimulus from the Flexi-Bar improves muscle strength, coordination, and balance ability¹⁹). Proper control (location, posture, and amplitude) of a vibration stimulus of Flexi-Bar by a distal limb segment (hand) affects lumbar stability²⁰).

The purpose of this study was to analyze the effect of the vibration stimulus provided by the Flexi-Bar during open kinetic chain exercise according to different shoulder joint angles and the most effective joint angle during the shoulder joint exercise.

SUBJECTS AND METHODS

A sample of 30 healthy male students who were 19 to 24 years of age and attending S University in Namwon city, Jeollabuk-do Province, Republic of Korea, were randomly selected. The subjects understood the purpose and procedure of this study and agreed to participate. All subjects provided written informed consent prior to participation according to the ethical standards of the Declaration of Helsinki.

The exercise groups, each consisting of 10 subjects, were as follows: group I (shoulder joint angle of 90°), group II (shoulder joint angle of 130°), and group III (shoulder joint angle of 180°). Those who had congenital anomalies or severe surgical or neurological disease of the upper limb, injury in upper limbs, or neck, back, or shoulder pain or who participated in a regular upper limb exercise program in the last six months were excluded. All subjects were right handed.

The average age, height, and weight of group I were 21.5±2.1 years, 173.8±5.2 cm, and 67.9±8.0 kg, respectively. Those of group II were 20.8±1.6 years, 174.5±3.7 cm, and 68.7±8.4 kg, respectively. Those of group III were 21.8±1.6 years, 174.7±4.9 cm, and 68.4±9.4 kg, respectively.

The subjects had adjustment period for 3–4 days to learn how to use the tool. They conducted warm-up stretching and walking for 5 minutes before the test.

The Flexi-Bar (Flexi-Sports, Bisley, Stroud, UK), an elastic bar made of glass fiber that is 1,520 mm long and weighs 719 g, was used as an exercise tool. It has a rubber grip (17.9 cm long, located in the middle of the bar, with rubber end weights). Holding the grip and shaking the bar delivers 5 Hz vibration throughout the hands, arms, and trunk.

Before the test, the subjects maintained a standing position facing forward with the feet 10 cm apart and arms in a neutral position. Adjustable bars were placed beside the subjects to control the height at which the Flexi-Bar was held such that it was at shoulder joint height. Guide bars were placed at 90°, 130°, and 180° in accordance with the shoulder joint angles for the Flexi-Bar as a guide to help subjects maintain the fixed angles. The test was conducted three times a week for 4 weeks. Four sets of 3 minutes of exercise and then 5 minutes of rest were conducted.

The Functional Reach Test (FRT) was used as an assessment tool. The subjects were in a standing position with the feet shoulder-width apart, and a ruler was placed horizontally at shoulder height. The subjects raised their arms straight out in front of them with their hands formed into fists and conducted elbow extension and shoulder joint flexion of 90°. While maintaining this position for 5 seconds, the location of the 3rd metacarpal head was marked and recorded. Measurements are presented as the mean values of three assessments²¹).

A Y-balance test kit (Move2Perform, Evansville, IN, USA) was used to test the stability of the shoulder joint. The Y-balance test is a dynamic balance test that evaluates muscle strength, flexibility, and proprioception related to shoulder joint instability. It is designed to be a standardized test and to increase the repeatability of measurement²²). The Y-balance test kit contains has a platform to which three PVC pipe rulers are attached in the anterior, posteromedial, and posterolateral directions, with reach indicators attached to each of them. The subject pushes a reach indicator for measurement. Each pipe is marked in 5 mm increments, and the anterior pipe is positioned 135° from the posterior pipes and the posterior pipes at 90° angles to each other. The length between the 7th cervical vertebra and index finger of each subject was measured for upper limb length measurement for normalization of reach distance values. The starting position was the push-up position with the feet shoulder-width apart. The subject had to start the test again if he missed the reach indicator, touched the floor, or failed to push the reach indicator with hands or to return to the start position during the movement. The test was conducted twice per direction in random order. The subjects had 2 minutes of rest between the tests.

PASW Statistics 18.0 for Windows was used to analyze the data. ANCOVA was conducted to investigate the differences in

each group between before and after the intervention. The Bonferroni test was used as a post hoc comparison test. The level of statistical significance was $\alpha=0.05$.

RESULTS

Analysis of covariance was conducted with values before the intervention as covariates to analyze the differences among groups I, II, and III in the FRT and Y-balance test. In the FRT, there were significant differences among the groups ($p<0.05$). Group I showed significantly greater improvement than group III according to the Bonferroni post hoc comparison ($p<0.05$) (Table 1). In the Y-balance test, there were significant differences among the groups ($p<0.05$). Group II showed significantly greater improvement than groups I and III according to the Bonferroni post hoc comparison ($p<0.05$).

DISCUSSION

The aim of this study was to introduce an effective shoulder joint exercise program using the Flexi-Bar, which generates a vibration stimulus, through comparison of functional stretching ability, proprioception, and stability according to different shoulder joint flexion angles between three groups and analyzing the differences among the groups.

Various movements of joints at different angles produce various postures. The efficiency of movements varies according to the angles between the bones and origin and insertion²³. Absolute muscle force, joint angle during measurement, and the length of force applied from the joint axis affects the expressed muscle strength²⁴. Fayad et al. introduced the scapulohumeral rhythm as the balance between the movements of the shoulder and glenohumeral joints²⁵. This showed that coordination between the scapula and shoulder joint, which is important for range of motion of the shoulder complex, is necessary to move the upper limb efficiently. Myers et al. presented that the shoulder joint has both mobility and stability²⁶.

The FRT was used to evaluate the range of motion of the shoulder joint. Group I showed greater improvement than group III. This result is in accordance with that of a study by An et al.¹³ who showed that muscles contracted most efficiently at an angle of 90° between the force and object surface. In addition, this result is considered to be the effect of low amplitude of 5 Hz from the Flexi-Bar, which was delivered to upper limb, shoulder, and then the whole body¹⁸. Therefore, the stability of the trunk and proximal joints improved.

The balance between the movements of the shoulder and glenohumeral joints is called the scapulohumeral rhythm, the scapulohumeral rhythm is important for the range of motion of the shoulder complex²⁵. Constant length-tension relationships among the surrounding muscles during glenohumeral joint movement should be maintained to provide stability of the scapula²⁷. The stability of the shoulder joint is closely related to improvement of proprioceptive function. The Y-balance test is a tool for dynamic stability evaluation of joints. Proprioception can be measured by maintaining the center of gravity of the upper limb and shoulder during this test²².

This study measured the stability of the shoulder joint using the Y-balance test. Shoulder stability improved in group II after the Flexi-Bar exercise more than in groups I and III. Tucker et al. reported that lower trapezius muscle activation increases with abduction of more than 90°, for example 125° and 145°²⁸. The moment arm shrunk when the upper and middle trapezius muscles were abducted to more than 90°, but it became longer when the lower trapezius muscle was abducted to more than 90°²⁹. Bogaerts et al. reported that a continuous vibration stimulus stimulated muscle spindles and improved proprioception, strengthening muscles involved in posture stability³⁰. A vibration stimulus strongly stimulates α -motor neuron and induces tonic vibration reflex because mechanical vibration applied to the muscle belly or tendon reflectively contracts muscles. Therefore, a vibration stimulus stimulates proprioception, acting as a greater external loads during exercise and increasing muscle activity of the upper limb and trunk according to the angle at which it is applied. The combination of existing shoulder rehabilitation therapies and an active vibration stimulus such as that generated by a Flexi-Bar can be a more effective tool for muscle activation and joint stability. More objective verification methods with various types of subject groups and more functional programs should be analyzed in further studies.

Table 1. Changes in the results of the FRT and Y-balance test after Flexi-Bar exercise

	Group I		Group II		Group III	
	Pre	Post	Pre	Post	Pre	Post
FRT (cm)*	89.4±5.0 ^a	92.1±4.6 [†]	92.2±4.8	94.0±4.1	92.9±6.6	91.5±5.5
Y-balance test (cm)*	45.8±7.1	50.1±5.9	46.6±7.1	56.5±7.4 ^{‡§}	43.2±6.1	47.6±5.0

^aMean±SD.

Group I: shoulder joint angle of 90°; Group II: shoulder joint angle of 130°; Group III: shoulder joint angle of 180°.

FRT: Functional Reach Test.

Significance was tested by ANCOVA.

*Between-group comparison ($p<0.05$)

Significance for multiple comparisons was tested by the Bonferroni multiple comparisons test.

[†]I>III ($p<0.05$). [‡]I<II ($p<0.05$). [§]II>III ($p<0.05$).

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