International Journal of Psychosocial Rehabilitation, Vol. 24, Issue 7,
2020 ISSN: 1475-7192

Comparison of EMG Activation of Tricpes Brachii and Serratus Anterior Muscle during Push-Up Exercise on Supported Surfaces

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Abstract

Background/Objectives*: The purpose of this study was to identify the effect of push-up exercise upon the sling and fixed surface on the triceps brachii and serratus anterior muscle activation.*

Methods/Statistical analysis*: Twenty healthy subjects agreed to the participation of this experiment and were those who met with the selection criteria. The subjects performed randomly the static and dynamic push-up exercise on the fixed surface, and the static and dynamic push-up exercise on the sling. While each push-up exercise was conducted on the surfaces, the triceps brachii and serratus anterior muscle activation was measured by surface electromyography (sEMG). Repeated ANOVA was used to compare the mean of EMG activation of the triceps brachii and serratus anterior muscle normalized by maximal voluntary isometric exercise.*

Findings*: The result showed that there was significantly different in triceps brachii long head muscle activation within the measure ($p<.05$), while there was not significantly different in the triceps brachii lateral head, and serratus anterior muscle ($p>.05$). The triceps brachii muscle activity showed a significant increase in the static push-up exercise upon the sling compared to the dynamic push-up exercise on the fixed surface and sling ($p<.05$). During the static push-up exercise on the sling, EMG activation of the triceps brachii long head significantly increased greater than the triceps brachii lateral head ($p<.05$). However, although there was no significant difference, in the static push-up exercise on the fixed surface, EMG activation of the triceps brachii long head was very increase ($p>.05$). Also, in the dynamic push-up exercise on the fixed surface and sling, EMG activation of the serratus anterior was very increase ($p>.05$).*

Improvements/Applications*: These findings suggest that static push-up exercise on sling can strengthen the triceps brachii long head muscle more effectively than the triceps brachii lateral head. That is necessary for the use of walker and wheelchair in patients with paraplegia.*

Keywords: *Electromyography, Push-up exercise, Serratus anterior, Sling, Triceps brachii long head.*

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1. INTRODUCTION

The triceps brachii muscle is divided into three muscle branches and the muscle extending elbow joint. Long head crosses the shoulder joint and, together with the deltoid and coracobrachialis, prevent the dislocation of the humerus. The use of pectoralis major and the triceps brachii muscle limit the movement of the scapulothoracic joints, resulting in stabilization of the trunk [1,2].

When using a walker, the weight shift is made by the triceps brachii and latissimus dorsi. Because the strengthening of these muscles is included in the preliminary gait training plan, it plays an important role in the use of walker [3]. Patients with paraplegia or quadriplegia require the function of the triceps brachii muscles to push the wheelchair in their daily lives. If this ability is insufficient, wheelchair users may experience shoulder impingement syndrome or carpal tunnel syndrome, and prevalence of musculoskeletal disorders such as carpal tunnel syndrome and upper limb injury may be increased [4].

Closed kinetic chain is a motion that occurs when the distal end of the limb is fixed and the resistance is applied simultaneously to the proximal and distal ends [5]. Closed kinetic chain exercise is widely used in exercise programs for joint stability and posture maintenance [6,7]. Davies [8] states that closed kinetic chain are typical of functional movements similar to daily activities or sports activities. For example, if your hands or feet support your weight and are fixed, like push-ups or squats.

Push-ups and modified push-ups are generally known as the typical closed kinetic chain movements of the upper limbs, as well as chest, shoulder and arm strength exercises. In addition to strengthening the chest and upper limbs and improving endurance, they also provide mechanical compression to the joint surface, resulting in cooperative contractions of the muscles around the shoulders [9,10].

Providing unstable ground at this time increases the effects of exercise to increase mobility and stability and improves neuromuscular control ability due to muscle weakness [11]. Recently, the interest in the field of physical therapy or sports is the active participation in the treatment process, which is more effective than the passive treatment method. As many studies [12] have progressed, the utilization of sling exercise therapy is increasing. In addition, proprioceptive sensations are stimulated to promote weakened muscles and prevent recurrence [13]

Oh et al. [13] compared muscle activity during push-ups on slings and fixed support surfaces. The push-up exercise on sling had no significant difference in the muscle activity of the triceps brachii compared to the exercise on the fixed support. Oh et al. [14] compared muscle activity according to the support surface interval during push-ups. There were significant differences in muscle activity of the triceps brachii according to the support surface interval. Weed and Kraemer [15] reported that the triceps brachii muscles became more active when pushed up with a narrow hand position.

Although there are studies on the trunk stability such as abdominis and waist on the unstable support surface using sling, there are not many papers that have combined various movements such as static and dynamic movements.

Therefore, the purpose of this study is to compare EMG activity of the triceps brachii and serratus anterior muscles when the normal adults in their 20s perform static and dynamic push-up exercise on the sling and fixed support surface. Thus, this study is to identify the effect of the unstable sling support surface and push-up movement for the strengthening of the triceps brachii and serratus anterior muscle.

2. METHODS

2.1. *Subjects*

Twenty healthy adult men were participated to test the effect of push-up exercise using sling at B University in Republic of Korea. The criteria for selecting the subjects were those who agreed to the participation with sufficient explanation for the purpose and procedure of the experiment. Those who had fracture or pain of upper extremity, congenital malformations, orthopedic and neurological diseases, and those who exercised regularly for 6 months were excluded.

The characteristics of the subjects are shown in Table 1.

Table 1. General characteristics of subjects (N=20)

Age (yrs)	Height (cm)	Weight (kg)
23.3±2.4*	174.9±5.6	73.1±9.5

*Mean ± Standard deviation.

2.2. *Experimental instrument*

2.2.1. Surface electromyography

To measure the maximum voluntary isometric contraction (MVIC) and muscle activation of the triceps brachii (long head, lateral head) and serratus anterior on push-up exercise upon supported surfaces, Trigno surface electromyography (Delsys Inc, Boston, USA) was used. The EMG signal was measured by the sensor of the electrode and transmitted wirelessly to the Trigno Base Station, which collected wirelessly to the PC for muscle activation analysis by EMGworks 4.0 software (Delsys Inc, USA).

The surface EMG electrodes was attached to the dominant side muscle of the subject and the electrode attachment placement for each muscle is shown in Table 2.

Table 2. EMG electrode placement

Muscle	Electrode placement
Triceps brachii long head	Middle area between acromion and olecranon, 2 cm inward from the centerline of the humerus
Triceps brachii lateral head	2 cm from the centerline of the humerus to the lateral side, between acromion and olecranon
Serratus anterior	between rib 6^{th} and 8^{th} in the middle axillary line

2.2.2. Sling

In this study, slings (Red cord, Therapimaster®, Norway) were used for dynamic and static push-up movements to provide support surface instability.

2.3. *Experimental methods*

MVIC and muscle activation of the triceps brachii and serratus anterior muscles were measured three times on each four movements for 5 seconds: static and dynamic push-up on the fixed support and sling. Subjects rested 2 minutes between push-up movements, and the sequence of exercises was randomized.

2.3.1. Data collection and procedure

Maximal voluntary isometric contraction (MVIC)

MVIC was measured to normalize the root mean square (RMS) of triceps brachii and serratus anterior on push-up on the supported surfaces. Normalization is necessary to prevent the difference between muscle strength [16].

For MVIC measurement of triceps brachii, the subjects were instructed to prone lying with the shoulders and elbows flexion 90° on the table. And if they extended their flexed elbow without shoulder rotation 90°, the experimenter gave the maximal resistance to the elbow flexion direction on their wrist joints.

For MVIC measurement of serratus anterior, the subjects sat with the shoulders flexion 125° on the table. The experimenter gave the maximal resistance to the shoulder extension direction on their elbow joint.

Triceps barchii and serratus anterior muscle activation in push-up on supported surfaces

The signal collected by the sEMG electrode on triceps brachii (long head and lateral head) and serratus anterior was stored as a digital signal, and the sampling rate was 1000 Hz, and band pass filter was from 5~300 Hz. The signal collected during each push-up exercise was saved into the computer via Root Mean Square (RMS) by AcqKnowledge 3.8.1 program. RMS was normalized by a percentage for MVIC.

2.3.2. Push-up exercise

Push-up on the fixed surface

Subject took the start position by looking at the floor from the floor with elbows straight. Exercise posture distributes weight across your hands and feet and tries to keep your shoulders, trunk and hips straight. The static push-up exercise was maintained as this posture for five seconds, and the dynamic push-up exercise was performed three times with one set of three times push-ups within five seconds. Each subject was repeated 3 times for 5 seconds, and the maximum value of the mean values for 3 seconds except the first and last 1 seconds was taken as the RMS value.

Push-up on the sling

The sling was positioned at the suspension point 25 cm above the floor. The subject places his both hands on the handle of the suspension point, looked at the floor with his elbows straight as starting position. Exercise posture distributes weight across your hands and feet and tries to keep your shoulders, trunk and hips straight. Static and dynamic push-up exercise was the same with the posture and data processing of the fixed surface.

2.4. *Statistical analysis*

Repeated ANOVA was performed to analyze the muscle activity of the triceps brachii and serratus anterior for the dynamic and static push-up on the support surface. SPSS ver.12.0 program was used to analyze statistically RMS collected through the experiment and the statistical significance level was a = .05.

3. Results And Discussion

The result showed that there was significantly different in triceps brachii long head muscle activation within the measure (p<.05), while there was not significantly different in the triceps brachii lateral head, and serratus anterior muscle (p>.05). The triceps brachii muscle activity showed a significant increase in the static push-up exercise upon the sling compared to the dynamic push-up exercise on the fixed surface and sling (p<.05). During the static push-up exercise on the sling, EMG activation of the triceps brachii long head significantly increased greater than the triceps brachii lateral head (p<.05). However, although there was no significant difference, in the static push-up exercise on the fixed surface, EMG activation of the triceps brachii long head was very increase (p>.05). Also, in the dynamic push-up exercise on the fixed surface and sling, EMG activation of the serratus anterior was increased insignificantly (p>.05) (Table 3).

Table 3. EMG activity in push-up exercise on supported surface (Unit : %)

	On the fixed surface		On the sling		F	*P*
Variables	Static push-up	Dynamic push-up	Static push-up	Dynamic push-up		
Triceps brachii long head	115.17±18.82[a]	106.18±21.53	144.73±21.04* **	86.90±16.08	5.78	.002
Triceps brachii lateral head	64.72±10.48	63.68±14.6	62.59±8.14	71.9±15.25	.18	.83
Serratus anterior	97.78±19.83	131.88±32.34	103.44±20.64	127.33±25.3	3.01	.67

[a]Mean ± Standard deviation.

*: In triceps brachii long head, the static push-up on the sling was significant increase compare to the dynamic push-up on the fixed surface and on the sling (p<.05),

**: In the static push-up on the sling, triceps brachii long head was more significantly increased than lateral head (p<.05)

EMG signals record motor unit action potentials that are generated in the muscle endplates of the muscle nerve junctions when muscles contract and relax and are conducted bilaterally along the muscle fibers to the tendons of each muscle fiber [17]. EMG can be used in various ways, including evaluating and analyzing the response of the exercise unit to determine whether it is normal or abnormal, and for determining diseases, evaluating exercise, analyzing muscles, and analyzing pain [18].

Sling exercise therapy is a therapeutic exercise approach aimed at improving physical discomfort, reducing pain, and increasing strength and endurance [19]. Sling exercise therapy is significant because most of the physiotherapy techniques we are currently using are passive approaches [20]. And it has a therapeutic effect on mobility, stretching, and sensory-motor training. However, scientific evidence is still lacking [21].

The purpose of this study was to investigate the push-up exercise for the strengthening of the triceps brachii and serratus anterior when performing push-up exercise on the fixed support surface and sling. The result showed that there was significantly different in triceps brachii long head muscle activation within the measure (p<.05). And during the static push-up exercise on the sling, EMG activation of the triceps brachii long head significantly increased greater than the triceps brachii lateral head (p<.05).

Maeo et al. [22] reported that in the pectoralis major muscle activity dynamic exercise was significantly higher than that of static exercise. However, in this study, unlike the previous studies, the muscle activity of the triceps brachii long head was increased in the static exercise rather than in the dynamic exercise. Some studies show that the change of support surface during push-ups does not affect the muscle activity of the muscles around the shoulder joint. However, in the result of this study, the triceps brachii long head was higher in the sling, that is, unstable surface, than the stable surface. As a similar result with this study, Lehman et al. [23] found that push-ups on Swiss balls were greater in the muscle activation of triceps brachii than push-ups on stable supports. Oh et al. reported that muscle activity was higher in push-ups on sling than in the fixed surface [13].

Triceps brachii long head is considered significant because it has a larger volume than any other muscle in the elbow, and has the larger volume needed for tasks requiring high work performance, functioning as a "preliminary" elbow muscle. However, triceps brachii lateral head showed high muscle activity, although there was no significant difference in muscle activity during the push-up exercise in the sling. The serratus anterior showed high muscle activity, although there was no significant difference in muscle activity during the push-up exercise on the fixed support surface.

The limitation of this study is that it is difficult to generalize because the number of subjects was small size, and age group was limited. And the lab environment wasn't controlled completely. In future studies, it should be considered that various ages, and increased subjects size with shoulder disease is included.

4. Conclusion

This study was conducted to investigate whether the supported surface and push-up exercise needed for strengthen-ing the triceps brachii and serratus anterior muscle strength were effective. As a result, there was a statistically significant increase in the triceps brachii long head when the static push-up was performed on the sling (p <.05). The muscle activation of triceps brachii lateral head and serratus anterior didn't matter the static or dynamic, and the supported surface. Therefore, the muscle activity of the triceps brachii long head can be strengthened effectively by the static push-up exercise on the sling. It would be more efficient to provide unstable support like sling and static movement when applied to the clinical rehabilitation program.

References

[1] Kohler JM, Flanagan SP, Whiting WC. Muscle activation patterns while lifting stable and unstable loads on stable and unstable surfaces. J Strength Cond Res. 2010Feb;24(2):313-321. DOI: 10.1519/JSC.0b013e3181c8655a.

[2] Schick EE, Coburn JW, Brown LE, Judelson DA, Khamoui AV, Tran TT, et al. A comparison of muscle activation between a Smith machine and free weight bench press. J Strength Cond Res. 2010Mar;24(3):779-784. DOI: 10.1519/JSC.0b013e3181cc2237.

[3] Kim MH. A study of the evaluation of the spinal cord injuries. The journal of Korean academy of physical therapy science. 1996;3(2):1011-1019.

[4] Louis N, Gorce P. Surface electromyography activity of upper limb muscle during wheelchair propulsion: influence of wheelchair configuration. Clin Biomech (Bristol Avon). 2010Nov;25(9):879-85. DOI: 10.1016/j.clinbiomech.2010.07.002.

[5] Kisner C, Colby LA. Therapeutic exercise: foundations and techniques. 4th ed. Philadelphia: FA. Davis; 2002.

[6] Beutler AI, Cooper LW, Kirkendall DT, Garrett WE Jr. Electromyographic analysis of sing-leg, closed chain exercises: implications for rehabilitation after anterior cruciate ligament reconstruction. J Athl Train. 2002Mar;37(1):13-18.

[7] Escamilla RF. Knee biomechanics of the dynamic exercise. Med Sci Sports Exerc. 2001Jan;33

[8] (1):127-41. DOI: 10.1097/00005768-200101000-00020

[9] Davis GJ. The need for critical thinking in rehabilitation. Journal of Sport Rehabilitation. 1995;4(1):1-22.

[10] Park JS, Jeon HS, Kwon OY. A comparison of the shoulder stabilizer muscle activities during push-up plus between persons with and without wing scapular. Korean Research Society of Physical Therapy. 2007;14(2):44-52. https://ir.ymlib.yonsei.ac.kr/handle/22282913/136019

[11] Ellenbecker TS, Davies GJ. Closed kinetic chain exercise: a comprehensive guide to multiple-joint exercise. Campaign: Human Kinetics; 2001. P. 7-17.

[12] Verhagen E, van der Beek A, Twisk J, Bouter L, Bahr R, van Mechelen W. The effect of the proprioceptive balance boarding training program for the prevention of ankle sprains: prospec- tive controlled trial. Am J Sports Med. 2004Sep;32(6):1385-93. DOI:10.1177/036354650326 2177

[13] Kim SY, Kim TY, Park SJ. A clinical application with the principle of hanging point in the sling. The Journal of Korean Academy Orthopedic Manual Physical Therapy. 2003;9(2):25-46. http://www.koreascience.or.kr/article/JAKO200327362747720.org

[14] Oh JS, Park JS, Kim SY, Kwon OY. Comparison of muscle activity during a push-up on a suspension sling and a fixed support. Korean Research Society of Physical Therapy. 2003;10(3):29-40. http://www.koreascience.or.kr/article/JAKO200316549673996.do

[15] Oh HS, Kim JY, Kim GE, Lee DH, Yoo NW, Choi HJ, et al. Journal of Korean Society of Integrative Medicine. Comparison of muscle activities in different supporting surface intervals during push-up exercise. 2013Dec;1(4):25-35. http://kiss.kstudy.com/thesis/thesis view.asp? key=3188839

Weed AT, Kraemer WJ. Muscle and fitness blueprint for arms. Muscle fitness insert. 2002.

[16] Newman SA, Jones G, Newham DJ. Quadriceps voluntary activation at different joint angles measured by two stimulation techniques. Eur J Appl physiol. 2003Jun;89(5):496-9. DOI: 10.1007/s00421-003-0836-0

[17] Basmajian JV, Deluca CJ. Muscles alive-Their function revealed by electromyography. 5th eds. Williams and Wilkins. Boltimore MD. 1986.

[18] Kang SY. Introduction to electromyography. Korean Journal of Pain. 1994;7(1):13-24. http://www.koreascience.or.kr/article/JAKO199431640759714.page

[19] Kim SY, Baek IH. Effects of transversus abdominal muscle stabilization exercise to spinal segment motion on trunk flexion-extension. Korean Research Society of Physical Therapy. 2003;10(1):63-73. http://www.koreascience.or.kr/article/JAKO200316549673909.page

[20] Kirkesola G. Advanced musculoskeletal course. The s-e-t concept using the therapimaster system. Norway: Course book; 2001.

[21] Kim SY, Kwon JH. Lumbar stabilization exercises using the sling system. Korean Academy of Orthopedic Manipulative Physical Therapy. 2001;7(2):23-39. http://www.koreascience.or.kr/article/JAKO200127362747527.page

[22] Maeo S, Chou T, Yamamoto M, Kanehisa H. Muscular activities during sling- and ground-based push-up exercises. Bio Med Central Research Notes. 2014March;7:192. doi:10.1186/1756-0500-7-192.

[23] Lehman GJ. The influence grip width and forearm pronation/supination upper-body myoelectric activity during the flat bench press. The Journal of Strength & Conditioning Research. 2005;19(3):587-591.