Journal of Oil & Applied Science
Vol. 35, No. 1. March, 2018. 36~42
ISSN 1225-9098 (Print)
ISSN 2288-1069 (Online)
http://dx.doi.org/10.12925/jkocs.2018.35.1.36

Electromyographic comparison of modified push-up exercise: focused on various arm position

You-Sin Kim · Jae-Young Yang · Nam-Ju Lee†

Department of Leisure Sports, School of Sports Science, Jungwon University, Goesan-gun, Chungbuk, 28024, Republic of Korea
Department of Physical Education, Graduate School, Jungwon University, Goesan-gun, Chungbuk, 28024, Republic of Korea
†*Department of Leisure Sports and Sports Health Medicine, School of Sports Science, Jungwon University, Goesan-gun, Chungbuk, 28024, Republic of Korea*
(Received January 15, 2018; Revised February 10, 2018; Accepted February 27, 2018)

Abstract : This study was to investigate the difference of muscle activities in trunk, upper arm, and shoulder during push-up exercise based on 3 types of different arm position(posterior position, PP; normal position, NP; and anterior position, AP) and to provide effective push-up arm position for each muscle development. Fifteen healthy males(age, 21.5±0.5 years; height, 172.7±1.0 cm; body mass, 70.5±1.3 kg; shoulder width, 42.3±0.6 cm; and BMI, 23.6±0.5 kg/m^2) participated in this study. PP, NP, and AP of the arm were used to conduct push-up exercise and 8 muscles(deltoideus p. acromialis: DA; pectoralis minor: PMI; pectoralis major: PMA; serratus anterior: SA; biceps brachii: BB; triceps brachii: TB; latissimus dorsi: LD; and infraspinatus: IS) of right side were selected to measure muscle activities. Total 9 counts of push-up exercise were conducted and EMG data signals of 5-time(from 3th to 7th) push-up movement were used for measuring muscle activities. PP push-up exercise showed that there was a significantly higher muscle activity of DA, PMI, PMA, SA, BB, LD, and IS(p<.05) and AP push-up exercise showed a significantly higher TB activity(p<.05). It would be suggested that different arm position evokes various muscle activities when conducting push-up exercise. PP would be the best push-up arm position for inducing various trunk, upper arm, and shoulder muscle activities compared to NP and AP.

Keywords : Push-up exercise, posterior position, normal position, anterior position, EMG

1. Introduction

Stabilizing musculature is defined as an ability for consciously or unconsciously controlling joint movement in the human body and thus, exercise program focusing on recovering balanced control capability in each muscle related to shoulder stabilization has been preferred for preventing shoulder function disorder, enhancing strength, and providing rehabilitation[1, 2]. To enhance stabilization and strength around the shoulder and the

†Corresponding author
(E-mail: namju1210@gmail.com)

trunk muscles, it would be very important to select proper exercise program for conducting rehabilitation protocol[3]. Moreover, relative strength of surrounded shoulder and trunk muscles should be considered as a crucial factor as well as considering enhancing actual muscle strength[4]. At this point of view, push-up exercise and modified push-up exercise has been emphasized as a closed kinetic chain exercise[5-7]. A closed kinetic chain exercise induces strength enhancement, aerobic capacity increase, and various muscle co-contraction through mechanical articular compression[8]. Therefore, it provides much more proprioception by stimulating afferent receptors around joint area and thus, it is one of the most common exercise therapy program component for providing dynamic stability of the joint and maintaining upright posture[8]. Push-up exercise, as a closed kinetic chain exercise, requires various muscle activities according to different arm position and therefore, push-up arm position would be the most crucial factor for trunk, upper arm, and shoulder muscle reinforcement training program and rehabilitation program. Moreover, shoulder rehabilitation period might be depended on the arm position for conducting rehabilitation program including push-up exercise[7]. Previous push-up exercise researches related to arm position found that there was significant difference in muscle activities among different arm position during push-up exercise. Cogley et al.[9] compared pectoralis major and triceps brachii muscle activity between the wide-width push-up arm group(85.8 cm) and the narrow-width push-up arm group(66.3 cm) and they found that narrow-width push-up arm group showed significantly higher pectoralis major and triceps brachii muscle activities compared to the wide-width push-up arm group. Also, Gouvali and Boudolos[10] conducted 6 types of modified push-up exercise(normal arm, abducted arm, adducted arm, posterior arm, anterior arm position, and push-up with the knee down to the floor position) and compared muscle activities. They reported that push-up with the knee down to the floor position showed significantly lower pectoralis major and triceps brachii muscle activities and posterior arm position showed higher pectoralis major activity and lower triceps brachii activity compared to other types of push-up exercise. Kim and colleagues[7] compared the difference of muscle activities among narrow-width push-up arm(50%), neutral-width push-up arm(100%), and wide-width push-up arm position(150%) and they found that narrow-width push-up arm position showed higher muscle activity in pectoralis minor, triceps brachii, and infraspinatus. They also reported that narrow- and neutral-width push-up arm position showed a higher muscle activity in pectoralis major and wide-width push-up arm position showed a higher muscle activity in serratus anterior. Based upon previous researches, push-up exercise may exert different muscle activation in the shoulder and trunk followed by various arm position; however, most previous researches set the arm position as narrow- and wide-width position[7, 9, 11] and in the posterior and anterior push-up arm position study, it only determined 2 muscles which was lack of investigating the effects of push-up exercise on the muscles in trunk, upper arm, and shoulder. Therefore, the purpose of this study was to investigate the difference of muscle activities in trunk, upper arm, and shoulder during push-up exercise based on 3 types of different arm position(posterior position, PP; normal position, NP; and anterior position, AP) and to provide effective push-up arm position for each muscle development. This study hypothesized that there would be different muscle activities in deltoideus p. acromialis(DA), pectoralis minor(PMI), pectoralis major(PMA), serratus anterior(SA), biceps brachii(BB), triceps brachii(TB), latissimus dorsi(LD), and infraspinatus(IS) based on 3 types of push-up arm position(PP,

NP, and AP).

2. Materials and Method

2.1. Participants

Fifteen healthy male volunteers(age, 21.5±0.5 years; height, 172.7±1.0 cm; body mass, 70.5±1.3 kg; shoulder width, 42.3±0.6 cm; and BMI, 23.6±0.5 kg/m^2), without any history of wrist, shoulder, and elbow injuries and no physical deformities, participated in this experiment. All participants fully understood this study purpose and they voluntarily participated in this study. This study was approved by the Institutional Review Board(IRB) for human subjects' protection at the "J" University and the informed consent was gained from all participants. The characteristics of this study participants are shown in Table 1.

Table 1. Characteristics of participants

Variables	
Age(years)	21.5±0.5
Height(cm)	172.7±1.0
Weight(kg)	70.5±1.3
Body-mass index(kg/m^2)	42.±0.6
Duration of low back pain(month)	23.6±0.5

Values are M±SD

2.2. Experimental approach to the problem

This study characterized the difference of muscle activities in trunk, upper arm, and shoulder during push-up exercise based on 3 types of different arm position(PP, NP and AP). This was accomplished by investigating the descriptive statistics of the mean. As such, the dependent variable of the current study was the muscle activity and the independent variable was the 3 types of the push-up arm position.

2.3. Procedures

Before conducting experiment, all participants were provided an information on 3 types of push-up exercise position(PP, NP, and AP) and they practiced 3 types of push-up exercise until they conducted natural push-up performance for familiarization. Three types of push-up exercise position(PP, NP, and AP) were selected by a random sampling method in each participant. Three types of push-up exercise position were determined as follows. The normal position(NP: 0%) of the arm was set as the shoulder-width arm position with 90-degree stand condition. The posterior position(PP: +30%) of the arm was set as the shoulder-width arm position with posterior stand condition and the anterior position(AP: -30%) of the arm was set as the shoulder-width arm position with anterior stand condition Figure 1[10]. Shoulder width was determined as the length between acromion in both sides of the shoulder[7]. Push-up exercise was conducted total 9 times and 5-time push-up movement measurement were selected from 3th to 7th, which was most natural performance[7]. One-time push-up count was determined as a full flexion and extension of both arms. DA, PMI, PMA, SA, BB, TB, LD, and IS of right side were selected

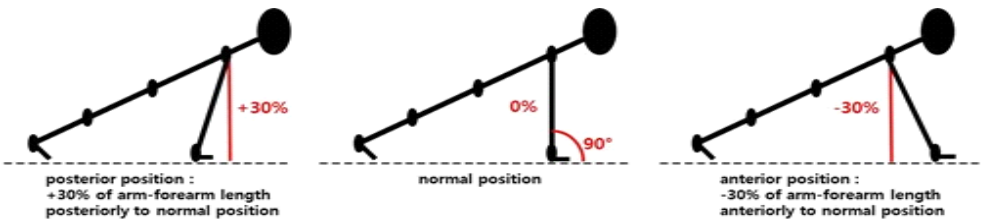

Fig. 1. Definition of 3 types of push-up posture.

for electromyography(EMG) analysis[12]. EMG exercise evaluation is a common way to measure the intensity of muscle activities[13]. T246H Ag-Ag/cl surface electrodes (Bio-Protech Inc., Korea) were attached on the 8 selected muscles. To synchronize video image and EMG data signal in each participant's push-up motion, a Raptor-E Camera(Motion Analysis Inc., USA) and 8 channels of Desk DTS EMG system(Noraxon USA Inc., Scottsdale, AZ) were used. EMG frequency band was set as 10-350 Hz and the sampling rate was set at 1,024 Hz by the MR-XP program(Noraxon USA Inc., Scottsdale, AZ). Collected EMG data signal was rectified and then it was processed by the root mean square(RMS) of 200 ms for data smoothing. The reference voluntary contraction(RVC) was used to standardize collected data as the %RVC method. This study set the standard RVC as the participant's push-up initial position with normal push-up arm position(0%) and the mean value was calculated by 3-time push-up measurement for 5 seconds. For steady speed of push-up exercise, a metronome application(Gismart Inc., London, UK) was used and 1-time push-up speed was set at 2.5 sec.

2.4. Statistical Analysis

IBM SPSS program(version 23.0; IBM Corporation, Armonk, NY, USA) was used for statistical analysis and the mean and standard deviation(mean±SD) was calculated for the descriptive statistics. To examine the difference of shoulder and trunk muscle activities based on 3 types of push-up position(PP, NP, and AP), one-way repeated measure ANOVA was used and post-hoc test was conducted by Tukey HSD. All statistical significance was set at $p<.05$.

3. Results

Table 2 shows that 8 muscle activity changes based on PP, NP, and AP. PP showed a higher muscle activity of DA($F_{(2,224)}$=35.34, $p<.001$), PMA($F_{(2,224)}$=50.09, $p<.001$), and IS($F_{(2,224)}$=110.04, $p<.001$). Post hoc test showed that there was a significant difference of muscle activity in PP, NP, and AP(AP<NP<PP). There was a significant higher PMI activity of PP and NP($F_{(2,224)}$=8.65, $p<.001$) and post hoc test showed that there was a significant difference of muscle activity in PP, NP, and AP(AP<NP, PP). There was a

Table 2. Muscle activities during 3 types of push-up

Muscle	M±SD (%RVC)		
	AP	NP	PP
DA***	240.0±11.6	345.8±21.0	494.6±29.1#
PMI***	507.0±17.9	568.1±15.3	602.5±16.1##
PMA***	498.0±21.6	616.5±18.0	808.8±26.1#
SA***	215.1±8.2	160.3±6.3	221.4±6.3§
BB***	180.6±9.2	160.3±10.1	421.2±33.2§§
TB***	506.0±27.0§§§	460.5±23.3	346.6±19.0
LD**	150.9±9.0§	119.8±6.9	145.3±5.9
IS***	102.±5.6	247.0±10.9	376.8±19.1#

Values are means ± standard deviations, AP: anterior position, NP: normal position, PP: posterior position, DA: deltoideus p. acromialis, PMI: pectoralis minor, PMA: pectoralis major, SA: serratus anterior, BB: biceps brachii, TB: triceps brachii, LD: latissimus dorsi, IS: infraspinatus, ***: $p<0.001$, **: $p<0.01$, #: AP<NP<PP, ##: AP<NP, PP, §: NP<AP, PP, §§: AP, NP<PP, §§§: PP<AP, NP

significant higher SA and LD activity of PP($F_{(2,224)}$=23.03, p<.001) and AP($F_{(2,224)}$=5.06, p<.01) and post hoc test showed that there was a significant difference of muscle activity in PP, NP, and AP(NP<AP, PP). There was a significant higher BB activity of PP($F_{(2,224)}$=49.15, p<.001) and post hoc test showed that there was a significant difference of muscle activity in PP, NP, and AP(AP, NP<PP). There was a significant higher TB activity of NP and AP($F_{(2,224)}$=12.43, p<.001) and post hoc test showed that there was a significant difference of muscle activity in PP, NP, and AP(PP<AP, NP).

4. Discussion

Main finding of this study was that there was a difference of muscle activity in DA, PMI, PMA, SA, BB, TB, LD, and IS based on 3 types of push-up arm position(PP, NP, and AP). PP push-up exercise showed that there was a significantly higher muscle activity of DA, PMI, PMA, SA, BB, LD, and IS(p<.05) and AP push-up exercise showed a significantly higher TB activity(p<.05). Push-up exercise has been considered as an optimal way to enhance muscle activity around scapula area including a middle serratus anterior(MSA) and a lower serratus anterior(LSA)[1, 14, 15]. Moreover, previous studies proved the way to strengthen serratus anterior muscle for stabilizing scapula[14, 15]. Push-up exercise has been used as a rehabilitation method for providing dynamic joint stability and maintaining posture because it evokes various muscle coordination contraction through mechanical compression of articular surface and provides more proprioception sense by stimulating afferent receptors around the joint area[15]. Modified push-up exercise can be applied by flexion and extension of the elbow joint, arm position(PP, NP, and AP), and kneeling or straitening legs in the sagittal plane, hand width condition(narrow, neutral, and wide position) in the frontal plane, and the tool availability. Several previous studies conducted modified push-up exercise. Wang et al.[16] examined ballistic push-up exercise with 60 healthy males and they divided 3 groups(T1 without external load; T2 with 10%; and T3 with 20% of their body mass). They reported that the peak and mean force of T3 was significantly higher than T2 and T1(p<.05). Park, et al.[17] conducted 3 push-up plus(standard push-up plus, the knee push-up plus, and wall push-up plus) exercise with 28 healthy adults(13 scapular winging group and 15 control group) and they compared muscle activity of PMA and SA. They found that there was a significant higher activity of PMA in the scapular winging group compared to the control group and there was a higher activity of SA in the control group compared to the scapular winging group. They also reported that the rate of PMA and SA activity was higher in the scapular winging group than the control group. Winged scapular has been well known to be occurred by weakened SA at resting and/or flexion or abduction of the upper extremity condition[18, 19] and previous studies mentioned the importance of SA strengthening to correct winged scapula. This study results proved and suggested that SA may be efficiently strengthened by push-up exercise based on different push-up arm position. Yoo[5] conducted wall push-up plus exercise and examined the muscle activity of SA with different wall condition(condition 1, stable wall push-up plus with the shoulder at 90 degrees of flexion; condition 2, stable wall push-up plus with the shoulder at 120 degrees flexion; and condition 3, labile wall push-up plus exercise with the shoulder at 90 degrees flexion). They reported that MSA in condition 3 was significantly higher than condition 1(p<.05) and LSA in condition 2 was significantly higher than condition 1(p<.05). As such, modified push-up exercise can be applied to enhance muscular strength with

various push-up condition and this study results also proved push-up exercise based on different push-up arm position may enhance muscular strength especially in the selected muscles. Similar as this study, Gouvali and Boudolos[10] divided 6 types of push-up exercise(normal, abducted, adducted, posterior, anterior, and on the knees position) and compared PMA and TB activity. They found that PMA activity was increased with narrow hand width condition and PMA and TB activity was decreased with kneeling the legs condition. In addition, the posterior arm position showed an increased PMA activity and decreased TB activity and the anterior arm position showed an increased TB activity, which was similar as this study results. Another modified push-up study[20] examined kinetic and myoelectric differences between 3 types of plyometric push-ups. Twenty-seven healthy, physically active men performed 2 series of 3 plyometric push-up variations; countermovement push-ups(CPUs) were push-ups performed with the maximum speed, jump push-ups(JPUs) were similar as clapping push-ups, and fall push-ups(FPUs) required kneeling participants. The results showed that FPU exercise achieved higher levels of muscular activation in the agonist and synergist muscle groups. Based upon previous studies, modified push-up has a strong advantage for strengthening intentionally selected muscles. To prescribe exercise training and/or rehabilitation programs specific to the enhancement of weak muscles in the shoulder and trunk, push-up exercise would be appropriately characterized for the training aim. The results of this study suggest that the push-up program can be practically applied to patients by enhancing functional disorder and improving muscular strength in the trunk, upper arm, and shoulder. Push-up exercise would be the recommended exercise method for patients because it can be easily conducted without any cost, place, difficulties, and time.

5. Conclusion

The push-up exercise can induce stabilization of trunk, upper arm, and shoulder muscles. It would be suggested that different arm position evokes various muscle activities when conducting push-up exercise. PP may induce various trunk, upper arm, and shoulder muscle activity compared to NP and AP. In addition, AP would be an effective arm position for developing TB. Based on this study results, there would be different muscle activities depending on push-up exercise arm position, which might be a critical factor for muscular development and rehabilitation.

Acknowledgments

This work was supported by the Jungwon University Research Grant(2016-106).

References

1. G. L. Moseley, P. W. Hodges, S. C. Gandevia, “Deep and superficial fibers of the lumbar multifidus muscle are differentially active during voluntary arm movements”. *Spine,* Vol.**27**, pp. 29-36, (2002).
2. K. De Mey, L. Danneels, B. Cagnie, D. Borms, Z. T 'Jonck, E. Van Damme, A. M. Cools, "Shoulder muscle activation levels during four closed kinetic chain exercises with and without Redcord slings". *J Strength Cond Res*, Vol.**28**, pp. 1628-1635, (2014).
3. J. B. Moseley Jr, F. W. Jobe, M. Pink, J. Perry, J. Tibone, "EMG analysis of the scapular muscles during a shoulder rehabilitation program". *Am J Sport Med*, Vol.**20**, pp. 128-134, (1992).
4. A. M. Cools, V. Dewitte, F. Lanszweert, D. Notebaert, A. Roets, B. Soetens, B. Cagnie, E. E. Witvrouw, "Rehabilitation of scapular muscle balance: which exercises

to prescribe"? *Am J Sport Med*, Vol. **35**, pp. 1744-1751, (2007).
5. W. G. Yoo, "Comparison of the middle and lower serratus anterior muscle activities during various wall push-up plus exercise". *J Phys Ther Sci*, Vol.**25**, pp. 153-154, (2013).
6. S. H. Cho, I. H. Baek, J. Y. Cheon, M. J. Cho, M. Y. Choi, D. H. Jung, "Effect of the push-up plus (PUP) exercise at different shoulder rotation angles on shoulder muscle activities". *J Phys Ther Sci*, Vol.**26**, pp. 1737-1740, (2014).
7. Y. S. Kim, D. Y. Kim, M. S. Ha, "Effect of the push-up exercise at different palmar width on muscle activities". *J Phys Ther Sci*, Vol.**28**, pp. 446-449, (2016).
8. T. S. Ellenbecker, G. J. Davies, *Closed kinematic chain exercise: A comprehensive guide to multiple joint exercise.* Human Kinetics Publisher; Champaign, IL, USA. p.53-58 (2001).
9. R. M. Cogley, T. A. Archambault, J. F. Fibeger, M. M. Koverman, J. W. Youdas, J. H. Hollman, "Comparison of muscle activation using various hand positions during the push-up exercise". *J Strength Cond Res,* Vol.**19**, pp. 628-633, (2005).
10. M. K. Gouvali, K. Boudolos, "Dynamic and electromyographical analysis in variants of push-up exercise". *J Strength Cond Res*, Vol.**19**, pp. 146-151, (2005).
11. H. S. Oh, J. Y. Kim, G. E. Kim, D. H. Lee, N. W. Yoo, H. J. Choi, P. J. Park, H. S. Hwang, E. H. Kim, D. Y. Kang, H. S. Kim, "Comparison of muscle activities in different supporting surface intervals during push-up exercise". *J Korean Soc Integ Med,* Vol.**1**, pp. 25-35, (2013).
12. R. Merletti, P. A. Parker, *Electromyography: Physiology, engineering, and non-invasive applications.* John Wiley & Sons, Hoboken, NJ, USA (2004).
13. J. Calatayud, S. Borreani, J. C. Colado, F. Martin, V. Tella, L. L. Andersen, "Bench press and push-up at comparable levels of muscle activity results in similar strength gains". *J Strength Cond Res,* Vol.**29**, pp. 246-253, (2015).
14. M. J. Decker, J. M. Tokish, H. B. Ellis, M. R. Torry, R. J. Hawkins, "Subscapularis muscle activity during selected rehabilitation exercises". *Am J Sport Med*, Vol.**31**, pp. 126-134, (2003).
15. P. M. Ludewig, M. S. Hoff, E. E. Osowski, S. A. Meschke, P. J. Rundquist, "Relative balance of serratus anterior and upper trapezius muscle activity during push-up exercises". *Am J Sport Med*, Vol.**32**, pp. 484-493, (2004).
16. R. Wang, J. R. Hoffman, E. Sadres, S. Bartolomei, T. W. Muddle, D. H. Fukuda, J. R. Stout, "Effects of different relative loads on power performance during the ballistic push-up". *J Strength Cond Res*, Vol.**31**, pp. 3411-3416, (2017).
17. K. M. Park, H. S. Cynn, O. Y. Kwon, C. H. Yi, T. L. Yoon, J. H. Lee, "Comparison of pectoralis major and serratus anterior muscle activities during different push-up plus exercises in subjects with and without scapular winging". *J Strength Cond Res*, Vol.**28**, pp. 2546-2551, (2014).
18. P. M. Ludewig, T. M. Cook, "Alterations in shoulder kinematics and associated muscle activity in people with symptoms of shoulder impingement". *Phys Ther*, Vol.**80**, pp. 276-291, (2000).
19. A. C. Lukasiewicz, P. McClure, L. Michener, N. Pratt, B. Sennett, "Comparison of 3-dimensional scapular position and orientation between subjects with and without shoulder impingement". *J Ortho Sport Phys Ther*, Vol.**29**, pp. 574-583, (1999).
20. X. García-Massó, J. C. Colado, L. M. González, P. Salvá., J. Alves, V. Tella, N. T. Triplett, "Myoelectric activation and kinetics of different plyometric push-up exercises". *J Strength Cond Res*, Vol.**25**, pp. 2040-2047, (2011).