วารสารวิทยาศาสตร์และเทคโนโลยีการกีฬา ปีที่ 16 ฉบับที่ 1, กรกฎาคม 2559
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นิพนธ์ต้นฉบับ (Original article)
วิทยาศาสตร์การโค้ช (Sports Coaching Science)

เปรียบเทียบการทำงานของคลื่นไฟฟ้ากล้ามเนื้อในขณะดันพื้น 3 ท่าที่แตกต่างกันในผู้ใหญ่สุขภาพดี

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บทคัดย่อ

การวิจัยนี้มีวัตถุประสงค์เพื่อ เปรียบเทียบผลของท่าดันพื้นที่แตกต่างกัน(ท่าดันพื้นปกติ, ท่าดันพื้นบนลูกบอล และท่าดันพื้นบนเชือก)ต่อการทำงานของคลื่นไฟฟ้าในกล้ามเนื้อ 4 มัดได้แก่กล้ามเนื้อหัวไหล่ด้านหน้า, กล้ามเนื้อหน้าอก, กล้ามเนื้อหน้าท้อง และกล้ามเนื้อหลังแขน ในผู้เข้าร่วมวิจัยเพศชายสุขภาพดี 17 คนที่มีส่วนร่วมในการศึกษาครั้งนี้ (ค่าเฉลี่ยอายุ = 22.76 ± 2.61 ปี, ค่าเฉลี่ยความสูง= 173.53 ± 4.84 เซนติเมตร, ค่าเฉลี่ยน้ำหนัก = 71.18 ± 8.04 กิโลกรัม, ค่าเฉลี่ยดัชนีมวลกาย = 23.57 ± 1.77 กิโลกรัมต่อเมตร^2)วันที่ทำการทดลอง, วัดลักษณะพื้นฐานทั่วไปและส่วนประกอบของร่างกายให้ผู้เข้าร่วมวิจัยอบอุ่นร่างกาย และยืดเหยียดกล้ามเนื้อ 10 นาทีจากนั้นจะสุ่มให้ทำท่าดันพื้นที่แตกต่างกัน3 ท่า(ท่าดันพื้นปกติ, ท่าดันพื้นบนลูกบอล และท่าดันพื้นบนเชือก) โดยขณะดันพื้นจะทำการวัดคลื่นไฟฟ้ากล้ามเนื้อทั้ง 4 มัดในการวิเคราะห์ผลใช้โปรแกรมสมาร์ทอนาไลซิส ตั้งค่าความถี่ในการวัดคลื่นอยู่ในช่วง 20-400เฮิร์ทซ และใช้สถิติแบบการวิเคราะห์ความแปรปรวนแบบทางเดียววัดซ้ำ เพื่อใช้วิเคราะห์ คลื่นไฟฟ้ากล้ามเนื้อและเปอร์เซ็นต์การหดตัวสูงสุดของกล้ามเนื้อ ผลการศึกษาพบว่าเปอร์เซ็นต์การหดตัวสูงสุดของกล้ามเนื้อของท่าดันพื้นบนลูกบอลสำหรับกล้ามเนื้อไหล่หน้าต่ำกว่าท่าดันพื้นแบบปกติ และท่าดันพื้นบนเชือกอย่างมีนัยสำคัญทางสถิติ (p<0.05), เปอร์เซ็นต์การหดตัวสูงสุดของกล้ามเนื้อในท่าดันพื้นบนลูกบอลสำหรับกล้ามเนื้อหน้าอกต่ำกว่าท่าดันพื้นแบบปกติ และท่าดันพื้นบนเชือกอย่างมีนัยสำคัญทางสถิติ (p<0.05), และเปอร์เซ็นต์การหดตัวสูงสุดของกล้ามเนื้อในท่าดันพื้นแบบปกติสำหรับกล้ามเนื้อหน้าท้องต่ำกว่าท่าดันพื้นบนลูกบอล และท่าดันพื้นบนเชือกอย่างมีนัยสำคัญทางสถิติ (p<0.05)สำหรับท่าดันพื้นบนเชือกเปอร์เซ็นต์การหดตัวสูงสุดของกล้ามเนื้อไหล่หน้า กล้ามเนื้อหน้าอกสูงกว่าท่าดันพื้นบนลูกบอลอย่างมีนัยสำคัญทางสถิติ และเปอร์เซ็นต์การหดตัวสูงสุดของกล้ามเนื้อหน้าท้องสูงกว่าท่าดันพื้นแบบปกติอย่างมีนัยสำคัญทางสถิติ(p<0.05) ผลการศึกษาที่น่าสนใจคือ เปอร์เซ็นต์การหดตัวสูงสุดของกล้ามเนื้อหลังแขนไม่มีความแตกต่างกันอย่างมีนัยสำคัญเมื่อเปรียบเทียบกับท่าดันพื้นที่แตกต่างกันทั้งสามท่า จากการศึกษาสรุปได้ว่าผลของคลื่นไฟฟ้ากล้ามเนื้อในการศึกษานี้แสดงให้เห็นว่า การดันพื้นในท่าดันพื้นบนเชือกทำให้กล้ามเนื้อหลังแขน, กล้ามเนื้อหน้าอก, กล้ามเนื้อหน้าท้องทำงานมากกว่า ท่าดันพื้นบนลูกบอล และในท่าดันพื้นบนเชือกแนะนำให้ฝึกสำหรับการฝึกขั้นสูง แต่ทว่าในท่าการดันพื้นบนลูกบอลแนะนำให้ฝึกสำหรับการฝึกแบบปานกลาง, ฝึกระบบประสาทสัมผัส หรือฝึกเฉพาะกล้ามเนื้อหลังแขน ตลอดจนใช้ฝึกเพื่อฟื้นฟูสมรรถภาพ สำหรับท่าดันพื้นปกติควรจะใช้ฝึกสำหรับกล้ามเนื้อหัวไหล่ด้านหน้า

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นิพนธ์ต้นฉบับ (Original article)
วิทยาศาสตร์การโค้ช (Sports Coaching Science)

COMPARISON OF THE ELECTROMYOGRAPHY DURING PUSH-UP EXERCISE WITH THREE DIFFERENT CONDITIONS IN HEALTHY ADULTS

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ABSTRACT

Objective: The aim of this study was to determine the effects of different push-up conditions (standard push-up (SDP), Swiss-ball push-up (SWP), and suspension push-up (SPP) on muscle activities of the anterior deltoids, pectoralis major, rectus abdominis, and triceps brachii muscles by using electromyography (EMG) analysis. Method: Seventeen healthy male subjects (mean age ±*SD* = 22.76 ± 2.61 years, mean height ±*SD*= 173.53 ± 4.84 cm, mean weight ±*SD* = 71.18 ± 8.04 kg, mean body mass index ± *SD* = 23.57 ± 1.77 kg/m^{-2}). On the experimental day, general characteristics and body composition were measured. After that, subjects were suggested to warm up and stretching for 10 minutes and then they were measured EMG of four different muscles while randomly performing 3 push-up conditions; (SDP), (SWP), and (SPP). Data analysis used smart analysis software, a Butterworth low-pass filter, with a cutoff frequency of 20 Hz for low-pass and 400 Hz for the high-pass. One-way ANOVA repeated measurement was used to determine normalized percentage of maximum voluntary contraction. Results: For (SWP) condition, results showed that %MVC values of anterior deltoids muscle had significantly lower than those of (SDP) and (SPP) (p<0.05). Pectoralis major muscle had significantly lower than (SDP) and (SPP) (p<0.05). And for (SDP) conditions, %MVC values of rectus abdominis muscle had significantly lower than (SWP) and (SPP) (p<0.05). For (SPP) condition, %MVC values of anterior deltoids and pectoralis major were significantly higher than (SWP) condition and %MVC values of rectus abdominis was significantly higher than (SDP) condition(p<0.05). Interestingly %MVC values of triceps brachii showed no significant difference when compare among three different conditions. Conclusion: The EMG results in this study showed that (SPP) condition can activate triceps brachii, pectoralis major, rectus abdominis muscles more than (SWP). And (SPP) condition for individual advanced training, whereas (SWP) condition would be recommended for moderate training, proprioception training or specific training especially triceps brachii muscle as well as rehabilitation training. For (SDP) condition, it could be used for only the anterior deltoids muscle.

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Keywords: EMG Push-up, Electromyography, Push-up devices, Push-up condition

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INTRODUCTION

Exercise is any bodily activity that improves the physical fitness and overall health, which can also help to develop the body functions such as cardiovascular function, muscle strength, and muscle endurance.[1–3] Performance of muscle body movement is enhanced by many ways and the effective movement depend on anatomical factors, neuromuscular skills, physiological capacities, and psychological background.[4] Push-up is the basic and popular exercise in the sports club, gymnasium, and fitness center which can develop upper body strength, local muscle endurance and power. It is performed for standard measurement of upper body muscle endurance.[5] Increased strength and muscle size of the upper body can be observed especially in pectoralis major, anterior deltoids, and triceps brachii muscles.[6] The load during a push-up is limited by an individual's bodyweight and anthropometry of subject.[7]

Recently, the comparison study of push-up surface found that performing push-up on unstable surface has greater effects on the muscles than stable surface.[8,9] In addition, several studies demonstrated an increase in muscle electromyography (EMG)while performing a push-up on common unstable conditions such as the Swiss-ball, and suspension.[3,6,10–12] Push-up with Swiss-balls, inflated discs, BOSU-ball push-up, and wobble boards enhance function of the upper body muscular such as pectoralis major, anterior deltoids, and triceps brachii muscles when compared with standard push-up conditions suggesting that muscle functions can be increased when subject perform exercise with instability conditions.[6,13] Interestingly, few studies have been proposed the relationship between push-up on the unstable surface and functions of rectus abdominal muscle[10,14] and latissimus dorsi muscles.[8] Moreover, data about the comparative research among different kinds of push-up conditions has not yet been clearly evaluated. Therefore, the main objective of this research was to determine effects of different push-up conditions (standard push-up, Swiss-ball push-up, and suspension push-up) on anterior deltoids, pectoralis major, rectus abdominis and triceps brachii muscle activities by using EMG analysis.

METHODS

Participants

Participants were 17 healthy male (mean age ±*SD* = 22.76 ± 2.61 years, mean height ±*SD*= 173.53 ± 4.84 cm, mean weight ±*SD* = 71.18 ± 8.04 kg, mean body mass index ± *SD* = 23.57 ± 1.77 kg/m^{-2}, mean length of left arm± *SD* = 74.78 ± 2.46 cm, mean length of right arm ± *SD*= 75.03 ± 2.55 cm) within the age range of 18-30 years. All of them usually go to either gymnasium or sports club for working out and are right-handed dominant. They had no record of injured or history of amyotrophic lateral sclerosis according to the terms of the American College of Sports Medicine guidelines[5.] Before started the experiment, participants were interviewed to complete a health history and inform consent. They were recruited through advertisement and social network.

Procedure

The experiment was performed at the 3rd Floor of Biomechanics laboratory, College of Sport Science and Technology, Mahidol University. On the first visiting, the demographic data of the participants including age, weight, height, and sex was recorded. The percentage of subcutaneous fatwas also measured using a voltage measurement (Omron (HBF-375)). Participants take off their shoes and stand on the board, while both hands holding two axes of the machine for one minute. After that, anthropometry measured by tape measure. For example, length of the left and right arms that were from acromion process to middle finger, left and right upper arms circumference by marking spine extending from acromion process to olecranon process and then marking upper arm length midpoint of triceps brachii muscle area for circumference measured, breath in and breath out chest circumference with tape measured that drag line through between both nipple, and arm muscle mass measured by Omron (HBF-375).On the second visiting, participants come to the laboratory one hour before starting and they were asked to warm up and stretch their muscles for 10 minutes. In preparation for the electrode attachment, we used surface electrodes and did the experiment with the same person[15.] Steps to prepare electrodes by using sandpaper to rub and clean then with cotton with alcohol to attached electrodes. Before the trial, warm up muscles by stretching for 10 minutes is reccomended[16.] Using Peter Konrad's method to measure EMG during maximum voluntary isometric contraction of 4 muscles groups was performed. Participants were trained correctly push up practices by a personal trainer. If participants cannot push-up properly, the default data were rejected from the process or excluded from the trial. Each condition repeated three times, speeds of push-up were controlled by a metronome. The length between hands and foot were calculated by 75% of the participant total height[17.] Times of push-up were constructed at least 3 second each time. Randomized conditions were used to for reduce bias trial. After the participants finished first condition, they were rested 15 minutes and switch to second and third condition, respectively[18–20.]

Statistical Analysis

Data was analyzed using SPSS/PASW Statistics version SPSS (version 18, Chicago, IL, USA). Means and standard deviations were calculated for the study characteristics. Mean and standard errors of mean for a result of EMG (anterior deltoids, pectoralis major, rectus abdominis and triceps brachii) one-way ANOVA repeated measurement were used to determine EMG (mV) and normalized (%MVC). To test normal distribution of data using Kolmogorov-Smirnov test. If data was not normal distribution using Friedman test. The level of statistical significance was $p<0.05$ and used the G-Power calculation. And sample for the reference population.

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RESULTS

The general characteristics of subjects

Seventeen subjects participated in this study. Characteristics of subjects were shown in Table 1. The average of age, weight, height, percentage of body fat and body mass index (BMI) were22.76±2.61 years (yr), 71.18±8.04 kilograms (kg), 173.53±4.84 centimeters (cm),16.02±2.84 percent (%), and 23.57±1.77 kilograms per meter^2(kg/m^2)respectively **(Table 1)**.

Table 1.Mean and standard deviation (mean ± S.D.) of general characteristics of subjects.

Characteristics	Mean±S.D. (n=17)
Age (years, yr)	22.76±2.61
Weight (kilogram, kg)	71.18±8.04
Height (centimeters, cm)	173.53±4.84
%Body fat (percent, %)	16.02±2.84
BMI (kilograms per meter^2, kg/m^2)	23.57±1.77

Anthropometrics data of subject

Anthropometrics data of subject were shown in Table2. Results were presented in mean and standard deviation (Mean±SD).The average length of left and right armswere74.78±2.46 cm and 75.03±2.55 cm. The average circumference of left and right arms were 31.31±2.42 cm and31.35±2.29 cm. The average of chest circumference during breath in and out were 97.29±4.97 cm and92.76±5.11cm. Arms muscle mass was 39.57±2.37% **(Table 2)**.

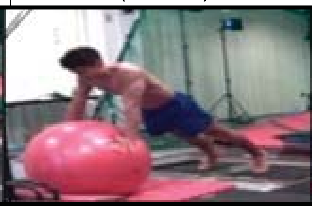
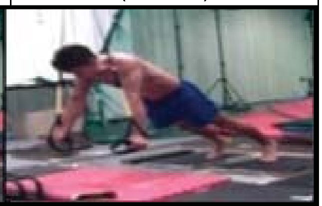
Table 2. Mean and standard deviation (S.D.) of the anthropometrics of subject

Anthropometrics	Mean±SD (n=17)
Length of the left arm (cm.)	74.78±2.46
Length of the right arm (cm.)	75.03±2.55
Left upper arm circumference triceps brachii(cm.)	31.31±2.42
Right upper arm circumference triceps brachii(cm.)	31.35±2.29
Breath in chest circumference (cm.)	97.29±4.97
Breath out chest circumference(cm.)	92.76±5.11
Arm muscle mass (%)	39.57±2.37

Percentage of maximum voluntary contraction values (%MVC) of muscles compare among three difference push-up conditions (standard push-up, Swiss-ball push-up, and suspension push-up)

%MVC values during the standard push-up, Swiss-ball push-up, and suspension push-up for anterior deltoids muscle were 75.30±3.70%, 50.37±4.09%, and 72.75±3.43%, respectively. Compare among three different push-up conditions, %MVC values of Swiss-ball push-up for anterior deltoid muscle had significantly lower than those of standard push-up and suspension push-up ($p<0.05$) **(Table 3).**

Table 3 Mean and standard error of mean (SEM) of muscles in each condition.

Muscles	standard push-up (%MVC)	Swiss-ball push-up (%MVC)	suspension push-up (%MVC)
			
Anterior deltoid	75.30±3.70%	50.37±4.09%[a]	72.75±3.43%[b]
Pectoralis major	58.67±4.86%	49.48±4.50%[c]	70.78±6.52%[d]
Rectus abdominis	12.98±0.95%	42.77±5.35%[e]	60.87±4.53 %[f]
Triceps brachii	68.61± 2.67%	69.79±2.77%	75.91±3.76%

[a]Significantdifferencebetween standard push-up and Swiss-ball push-up($p<0.05$)

[b]Significant difference between Swiss-ball push-up and suspension push-up ($p<0.05$)

[c]Significant difference between standard push-up and Swiss-ball push-up ($p<0.05$)

[d]Significant difference between Swiss-ball push-up and suspension push-up ($p<0.05$)

[e]Significant difference between standard push-up and Swiss-ball push-up ($p<0.05$)

[f]Significant difference between standard push-up and suspension push-up ($p<0.05$)

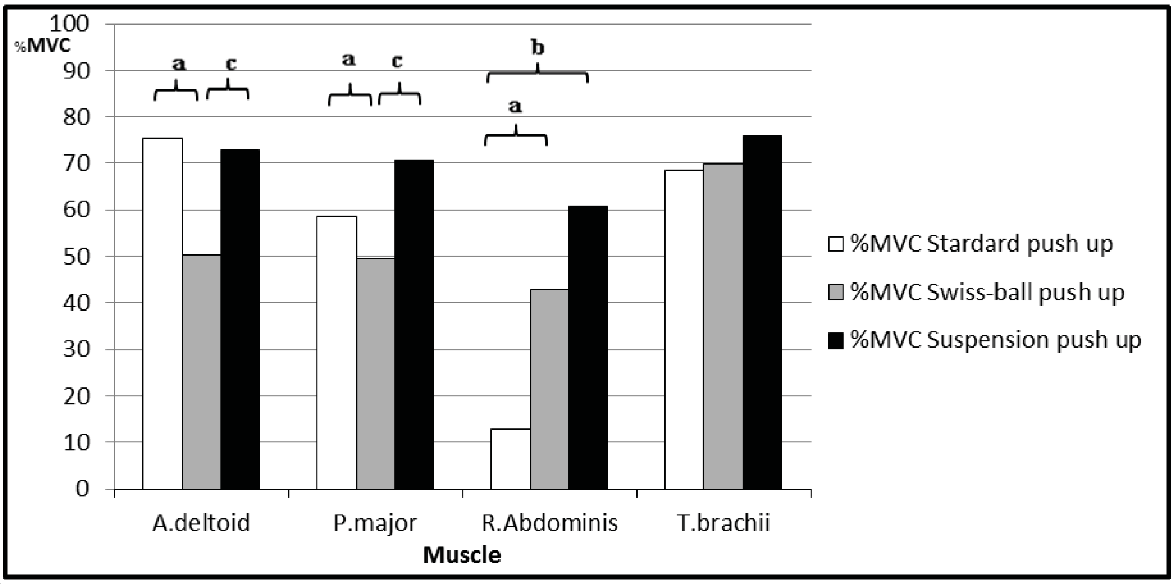
%MVC values of pectoralis major muscle during the standard push-up, Swiss ball push-up, and suspension push-up were 58.67±4.86%, 49.48±4.50%, and 70.78±6.52%, respectively. Compare among three different push-up conditions, %MVC values of Swiss-ball push-up for pectoralis major muscle had significantly lower than standard push-up and suspension push-up ($p<0.05$) **(Table 3).**

%MVC values of rectus abdominis muscle activity during the standard push-up, Swiss-ball push-up, and suspension push-up was 12.98±0.95%, 42.77±5.35%, and 60.87±4.53%, respectively. Compare among three different push-up conditions, %MVC values of standard push-up for rectus abdominis muscle had significantly lower than Swiss-ball push-up and suspension push-up ($p<0.05$) **(Table 3).**

%MVC values of triceps brachii muscle activity during the standard push-up, Swiss-ball push-up, and suspension push-up was 68.61± 2.67%, 69.79±2.77%, and 75.91±3.76%, respectively. There were no significant difference in %MVC values when compare among three different push-up conditions for triceps brachii muscle (p>0.05) **(Table 3).**

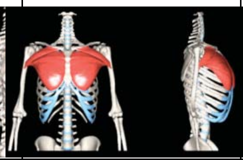
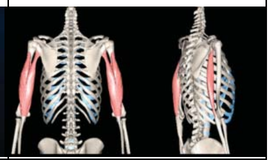
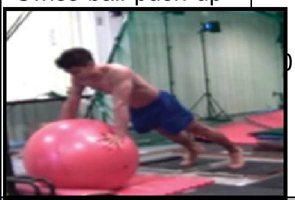
Compare among four different type muscles, %MVC values of anterior deltoids for Swiss-ball push-up had significantly lower than standard push-up and suspension push-up (p<0.05). %MVC values of pectoralis major for Swiss-ball push-up had significantly lower than standard push-up and suspension push-up (p<0.05). %MVC values of rectus abdominis for standard push-up had significantly lower than Swiss-ball push-up and suspension push-up (p<0.05). And %MVC values of triceps brachii, had no significant difference among three different push-up conditions **(Fig.1) (Table 4).**

Figure 1



[a]Significant difference between standard push-up and Swiss-ball push-up (p<0.05)
[b]Significant difference between standard push-up and suspension push-up (p<0.05)
[c]Significant difference between Swiss-ball push-up and suspension push-up (p<0.05)

Table 4 Mean and standard error of mean (SEM)of condition in each muscles.

Muscles	Anterior deltoids	Pectoralis major	Rectus abdominis	Triceps brachii
				
Standard push-up 	[illegible].30±3.70% a	58.67±4.86% a	12.98±0.95% a	68.61± 2.67%
Swiss-ball push-up 	[illegible].37±4.09% b	49.48±4.50% b	42.77±5.35% c	69.79±2.77%
Suspension push- 	[illegible].75±3.43%	70.78±6.52%	60.87±4.53 %	75.91±3.76%

[a]Significant difference between standard push-up and swiss-ball push-up (*p*<0.05)
[b]Significant difference between swiss-ball push-up and suspension push-up (*p*<0.05)
[c]Significant difference between standard push-up and suspension push-up (*p*<0.05)

DISCUSSION

The main purpose of this study was to compare EMG data among four different muscle types which were anterior deltoids, pectoralis major, rectus abdominis, and triceps brachii muscles while performing push-up on three different conditions (standard push-up, Swiss-ball push-up, and suspension push-up).Results found that **anterior deltoids muscle** showed a much more values during a standard push-up than during suspension push-up and Swiss-ball push-up respectively. This results were similar to the previous study[11]which found that anterior deltoids muscle is the most strongly activated muscle while performing standard push-up condition. Moreover, the activity of **pectoralis major** muscle during suspension push-up showed greater activated than during standard push-up and Swiss-ball push-up, respectively, which is similar to the previous study.[10] For **rectus abdominis muscle**, this muscle was the best activated muscle during perform suspension push-up condition as well as Swiss-ball push-up, respectively which also was corresponded to the previous study.[11,24] However in previous studies revealed that standard push-up by rectus abdominis was activated less than lower body instability with stability ball, upper body instability with the extreme balance board, and dual instability with the stability ball conditions.[9] **Triceps brachii** muscle showed better activation during suspension push-up condition than during Swiss-ball push-up and standard push-up, respectively. This result is similar to the previous research[11,9] which could be indicated that triceps brachii muscle had no different activities between stable push-up and upper body instability push-up. In contrast, the recent research was done by Ronald L. Snarr (2013)reported that triceps brachii muscle is lower activated during traditional push-up than during suspension push-up[10], whereas our results indicated that the activation of triceps brachii muscle had no significant difference during performing among three push-up conditions.

For standard push-up condition, the increases of EMG muscle activities of anterior deltoid, pectoralis major and triceps brachii were similar to the result shown in the previous study.[6,10,22]In addition, we found that rectus abdominis muscle was activated less than other muscles because this condition was a stable kinetic-chain.[25] Its structure is close to stable surface resulting in smaller rectus abdominis activation, they were similar to previous study.[22] Another similar research of Gregory 2006 had shown that increased rectus abdominis muscles activity when subject's hands close to the unstable surface.[26]

For Swiss-ball push-up condition, we found that anterior deltoids, pectoralis major, rectus abdominis muscles were activated equally except triceps brachii muscle found to be activated more than the others, suggesting that triceps brachii muscle is an essential muscle for controlling ball during Swiss-ball push-up condition. Similar to the previous research,[26] they found that triceps brachii was activated more than pectoralis major and rectus abdominis muscles. In previous study, they suggested Swiss-ball push-up condition can be used for rehabilitation program and help to increase muscle activity in upper/middle trapezius and serratus anterior but not in triceps brachii muscles.[27]

For suspension push-up condition, the most activated muscle was triceps brachii muscle, since this condition is an unstable kinetic-chain, therefore groups of upper limb and trunk muscles have to work harder than stability condition.[28] Our results were contrasted to Ronald L. Snarr 2013 who found that lying hands position on the rope showed no significant difference of triceps brachii activation among the others conditions. However recently study and Calatayud J. 2014 and So Young Jeong 2014 reported that increase triceps brachii activities in suspension push-up, these could be suggested that upper extremities muscles especially triceps brachii muscle are essential to stabilize the body while performing this condition.

CONCLUSION

Results in this study can be concluded that for standard push-up condition, it could be used only triceps brachii muscle as well as rehabilitation training lower limb muscles injuries such as knee and ankle injuries. Swiss-ball push-up condition would be recommended for moderate training, proprioception training and specific triceps brachii training as well as rehabilitation program training. For advance push-ups training, we would recommend suspension push-up because this condition can strongly activated triceps brachii, pectoralis major, and rectus abdominis muscles much more than other conditions. In summary, this study reveals the beneficialeffects of3 different push-up conditions. The results could be used by trainer to select an appropriate push-up condition for developing upper body strength, local muscle endurance and power in individual people.

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REFERENCES

1. Dillman CJ, Dillman CJ, Murray TA, Hintermeister RA. Biomechanical differences of open and close chain exercises with respect to the shoulder. J Sports Rehab. 1994; 3: 228-38.
2. Ubinger M, Prentice W, Guskiewicz K. Effect of closed kinetic chain training on neuromuscular control in the upper extremity. J Sport. 1999;8(3):184–94.
3. Tim L.l, Thomas J, Carl G,Scott D. Shoulder musculature activation during upper extremity weight-bearing exercise. J Orthop Sports Phys Ther. 2003;33(3):109–17.
4. Knudson D.Fundamentals of Biomechanics:department of kinesiology california State University at Chico First & Normal Street Chio C 95929-0330 USA. Springer science Publishing; 2007
5. Thompson WR. American College of Sports Medicine. ACSM'S Health-Related Physical Fitness Assessment Manual (4th ed.)Philadelphia, PA: Wolters Kluwer/Lippincott Williams & Wilkins, 76-91; 2013.
6. James W, Brian D, Jay V, Craig M, Kevin R, and John H. Comparison of muscle-activation patterns during the conventional push-up and perfect· pushupTM exercises. J Strength Cond Res. 2010;24(12):3352–62.
7. Contrers B, Brad Sc, Jonathan M, Gul Tiryaki-Sonmez JC. The biomechanics of the Push-up: Implications for Resistance Training Programs. Natl Strength Cond Assoc. 2012;34(5):41–6.
8. Tyson AC, Samuel J, Jack P. Muscular contribution to low-back loading and stiffness during standard and suspended push-ups. Hum Mov Sci. 2008;27(3):457–72.
9. Anderson GS, Gaetz M, Holzmann M, Twist P. Comparison of EMG activity during stable and unstable push-up protocols. Eur J Sport Sci. 2013;13(1)(january):42–8.

10. Ronald L, Michael R. Electromyographic comparison of traditional and suspension push-ups. J Hum Kinet. 2013;39(1):75–83.

11. Joaquin C, Borreani S, Colado JC, Fernando MF, Rogers ME, Michael E, David GB, Lars L. Muscle activation during push-muscle Activations during Push-Ups with different suspension training systems. J Sport Sci Med. 2014;13 February :502–10.

12. So Young J, Sin Ho Chu, Jae Hum H. Comparison of upper trapezius, anterior deltoid, and serratus anterior muscle activity during push- up plus exercise on slings and a stable surface. J Phys Ther Sci. 2014;26:937–9.

13. Gregory J, Danielle G. An unstable support surface does not increase scapulothoracic stabilizing muscle activity during push up and push up plus exercises. Man Ther.2008;13:500-6.

14. Freeman S, Karpowicz A, Gray J, McGill S. Quantifying muscle patterns and spine load during various forms of the push-up. Med Sci Sports Exerc. 2006;38(3):570–7.

15. Florimond V. Basics of surface electromyography applied to physical rehabilitation and. Thought Technol Ltd. 2010;1(March):1–50.

16. Peter K. The ABC of EMG a Practical introduction to kinesiological electromyography.Noraxon INC. USA. Publishing; 2006. 1-61.

17. Steven W, Campbell BM, Swartz EE, Armstrong CW. Electromyography of 3 scapular muscles: A comparative analysis of the cuff link device and a standard push-up. J Athl .Train. 2008;43(5):464–9.

18. Merton PA. Voluntory strenght and fatigue. J Physiol. 1954;123:553–64.

19. Stephens JA, Taylor A. Fatigue of maintained voluntary muscle contraction in man. J Physio. 1972;220:1–18.

20. Edwards RHT, Hill DA, D.A. Jones DA, Merton PA. Fatigue of long duration in human skeletal muscle after exercise. J Physiol. 1977;272(3):769–78.

21. Floyd RT. Manual of structural kinesiology. Boston: McGraw-Hill Publishing; 2009.

22. Maeo S, Chou T, Yamamoto M, Kanehisa H. Muscular activities during sling- and ground-based push-up exercise. BMC Research Notes; 2014; Mar 7(1):192–8.

23. Marshall PW, Dip PG, Murphy BA. Core stability exercises on and off a swiss ball. Arch Phys Med Rehabil. 2005;86(2):242–9.

24. Maeo S, Takahashi T, Takai Y, Kanehisa H. Trunk muscle activities during abdominal bracing: Comparison among muscles and exercises. J Sport Sci Med. 2013;12(3):467–74.

25. Max P, Christopher D, Edward N, Frank I, Glenn A, Arthur W. Closed-kinetic chain upper-body training improves throwing perfomance of NCAA division I softball player. J Strength Cond Res. 2008;1790–8.

26. Lehman GJ, MacMillan B, MacIntyre I, Chivers M, Fluter M. Shoulder muscle EMG activity during push up variations on and off a Swiss ball. Dyn Med. 2006; june: 5-7.

27. Seo SH, Jeon IH, Cho YH, Lee HG, Hwang YT, Jang JH. Surface EMG during the push-up plus Exercise on a Stable Support or swiss ball: Scapular stabilizer muscle exercise. J Phys Ther Sci. 2013;25(7):833–7.

28. McCaw ST, Friday JJ. A comparison of muscle activity between a free weight and machine bench press. J Strength Cond Res. 1994; 8(4):259-64.

29. Gouvali MK, Boudolos K. Dynamic and electromyographical analysis in variants of push-up exercise. J Strength Cond Res. 2005;19(1):146–51.

30. Wurm B, VanderZanden TL, Spadavecchia M, Durocher JJ, Bickham CT, Petushek EJ, Ebben WP. Kinetic analysis of several variations of push ups. J Strength Cond Res. 2011;25(10): 2891–94.