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Electromyographic Activities of Pectoralis Major and Triceps Brachii Muscles During Push-Up Exercises on Different Surfaces

Farklı Yüzeylerde Yapılan Şınav Egzersizleri Sırasında Pectoralis Major ve Triceps Brachii Kaslarının Elektromiyografik Aktiviteleri

Erbil Murat Aydın [1], * Burak Gündoğan [2], Ali Fatih Sağlam [3]

[1] *Faculty of Sport Sciences, Hitit University, Çorum, TÜRKİYE / emurataydin@hitit.edu.tr / 0000-0003-2825-4873*
[2] *Faculty of Sport Sciences, Hitit University, Çorum, TÜRKİYE / burakgundogan@hitit.edu.tr / 0000-0003-2516-4696*
[3] *Institute of Postgraduate Studies, Çanakkale Onsekiz Mart University, Çanakkale, TÜRKİYE / alifatihsaglam@gmail.com / 0000-0002-5761-7154*
* *Corresponding author*

Abstract: The push-up (PU) is a basic exercise commonly used in strength training. This exercise can be performed on different surfaces. The purpose of this study was to compare the muscle activation of the pectoralis major and triceps brachii muscles during PU exercises performed on stable and unstable surfaces. Nineteen males participated in this study. Bosu ball and gymnastics rings apparatus were used as unstable surfaces and the floor was used as a stable surface. Subjects performed 5 repetitions of PU on the different surfaces. A one-way repeated-measures analysis of variance was used to compare the muscle activities between the surfaces. Muscle activation of PM was significantly greater in the gymnastics rings than on the floor and the Bosu ball ($p<0.001$). No significant difference was determined when the floor and the Bosu ball were compared. There was no significant difference between surfaces in the muscle activation of TB ($p>0.05$). In conclusion, using the gymnastics rings apparatus as an unstable surface increases the PM muscle activation in PU exercise. Muscle activation of TB was not influenced by surface stability in PU.

Keywords: Unstable surface, stable surface, muscle activity.

Özet: *Şınav kuvvet antrenmanlarında yaygın olarak kullanılan temel bir egzersizdir. Bu egzersiz farklı yüzeylerde yapılabilir. Bu çalışmanın amacı, stabil ve stabil olmayan yüzeylerde gerçekleştirlien şınav egzersizi sırasında pektoralis major (PM) ve triceps brachii (TB) kaslarının kas aktivasyonlarını karşılaştırmaktır. Bu çalışmaya on dokuz erkek katılmıştır. Stabil olmayan yüzeyler olarak Bosu topu ve cimnastik halkası, stabil yüzey olarak ise düz bir zemin kullanılmıştır. Katılımcılar, farklı yüzeylerde 5 tekrar şınav gerçekleştirmiştir. Yüzeyler arasındaki kas aktivasyonlarının karşılaştırılmasında tekrarlı ölçümlerde tek yönlü varyans analizi kullanılmıştır. PM kas aktivasyonu, halka aletinde Bosu topu ve stabil yüzeyden anlamlı düzeyde yüksek bulunmuştur ($p<0.001$). Bosu topu ve stabil yüzey karşılaştırıldığında ise anlamlı fark saptanmamıştır ($p>0.05$). TB kas aktivasyonunda ise yüzeyler arasında anlamlı fark bulunmamıştır ($p>0.05$). Sonuçta, şınav egzersizinde halka aletinin stabil olmayan bir yüzey olarak kullanılması, PM kas aktivasyonunu artırmıştır. Şınav egzersizinde TB kas aktivasyonunun ise yüzey stabilitesinden etkilenmediği görülmüştür,.*

Anahtar Kelimeler: *Stabil olmayan yüzey, stabil yüzey, kas aktivasyonu.*

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INTRODUCTION

The practice of unstable surfaces in strength training has increased. Unstable surfaces such as Bosu balls, Swiss balls, and TRX are used in resistance training to improve performance. Unstable surface exercises increase the demand on the neuromuscular system to stabilize the joints and muscles of the body, resulting in more muscle activation (Lehman et al., 2006). Thus, it has been reported that using unstable surface materials causes more muscle stress (Behm & Anderson, 2006; de Araújo et al., 2020; de Oliveira et al., 2008; Freeman et al., 2006; Gioftsos et al., 2016; Marshall & Murphy, 2005; Steckey, 2004; Tucker et al., 2010; Vera-Garcia et al., 2000). The rationale for using an unstable surface is based on the potential for increased muscle demand necessary to sustain postural stability, although there is insufficient evidence (Marshall & Murphy, 2006a). Suspension devices could be used to provide unstable surfaces. Gymnastics rings is a kind of suspension device. Beach et al. (2008) stated that using the suspension device increased abdominal muscle activation. Calatayud et al. (2014b) compared some muscle activations during PU performed on different suspension devices. They concluded that all suspension systems were effective in achieving high levels of rectus abdominis muscle activation.

Surface electromyography (sEMG) is a method used to determine the electrical activity of muscles using surface electrodes. The electromyography signal originates from motor unit action potentials (Graţiela-Flavia et al., 2009). sEMG is a non-invasive technique used in different fields such as sports science, neurophysiology and rehabilitation (Rainoldi et al., 2004). In biomechanics, the surface EMG signal is often used to obtain information about the initiation of muscle activation, force production by a muscle, and fatigue in a muscle (De Luca, 1997). Maximum voluntary isometric contraction (MVIC) is a commonly used method for EMG amplitude normalization (Norcross et al., 2010). The normalization should be used to compare muscle activities between different muscles, times, and subjects (Burden & Bartlett, 1999).In the literature, there are studies examining the effects of unstable surfaces on trunk muscle activities. Some studies report significant increases in certain trunk muscles during curl-up exercises on labile surface (Vera-Garcia et al., 2000) and upper body exercises while sitting on an exercise ball (Behm et al., 2005). Anderson and Behm (2004) suggest that using an unstable surface requires more muscle activation than a stable surface to generate the same amount of force. Another study reported significant improvements in shoulder joint proprioception following rehabilitation treatment using an unstable surface (Naughton et al., 2005). The use of a Swiss ball as an unstable surface may result in increased muscle activation (Marshall & Murphy, 2006a). However, Lehman et al. (2006) reported that there was no significant difference in the muscle activity of the pectoralis major (PM) muscle in PU exercise when the hands were on stable and unstable surfaces.

The PU is widely used in strength training. PU is also a common exercise for beginners as it does not require any equipment and can be performed with body weight. The aim of PU is to strengthen primarily PM and TB (Cogley et al., 2005). The PU exercise is effective, especially in shoulder improvement protocols (Park et al., 2014; Pirauá et al., 2014) for the upper body muscles (Ashnagar et al., 2016; Borreani et al., 2015b; Calatayud et al., 2014a; Cogley et al., 2015; de Araújo et al., 2020; Freeman et al., 2006; Gioftsos et al., 2016; Marshall & Murphy, 2006a; McGill et al., 2014; Snarr & Esco, 2013; Tucker et al., 2010;) and is widely recommended. This exercise is especially important for the activation of the pectoralis major, triceps brachii (Ashnagar et al., 2016; Calatayud et al., 2014a; Cogley et al., 2005; Freeman et al., 2006; Marshall & Murphy, 2005; Snarr & Esco, 2013), serratus anterior, and trapezius (Ashnagar et al., 2016; de Araújo et al., 2020; Ludewig et al., 2009; Tucker et al., 2010) muscles. PU is an exercise performed to increase the dynamic stability of the upper extremity. At the initial phase of the PU, the hands are placed on the floor directly under the shoulders and stand with the feet shoulder-width apart (Kowalski et al., 2022). Then the body lowers to the floor by flexing the elbow after the elbow reaches 90° flexion the body is returned to the initial position (Freeman et al., 2006).

PU can be performed in different variations. PU variations can be obtained by commonly changing body position, joint angles, and stability of the external environment (Batbayar et al., 2015; Borreani et al., 2015a; Calatayud et al., 2014b; Cho et al., 2014; Kang et al., 2014). Different PU variations can be obtained by changing the hand and leg positions (Dhahbi et al., 2022). In addition, different PU variations can be provided by changing the surface performed PU. Cogley et al. (2005) examined muscle activations of PM and TB during PU performed with different hand positions. They stated that narrow hand placement in PU leads to greater muscle activation in PM and TB than wider hand placement. Lee et al. (2013) reported that PU performed with the externally rotated hand position on an unstable surface provided more serratus anterior muscle activation than the stable surface and the other hand positions. They found that muscle activation of PM was not influenced by surface stability and hand positions. On the other hand, Anderson et al. (2013) found that muscle activity increased with increasing instability levels. Kim et al. (2014) reported that greater serratus anterior muscle activity was observed on an oscillating unstable surface than on a static unstable surface and stable surface during knee PU plus exercise. Our study was conducted to determine the effects of surface stability on muscle activations of the PM and TB muscles during PU. It was hypothesized in this study that the PU performed on an unstable surface would lead to a greater activation of PM and TB.

METHODS

Research Model: The crossover design was used in this study. The sudy design was given in Figure 1.

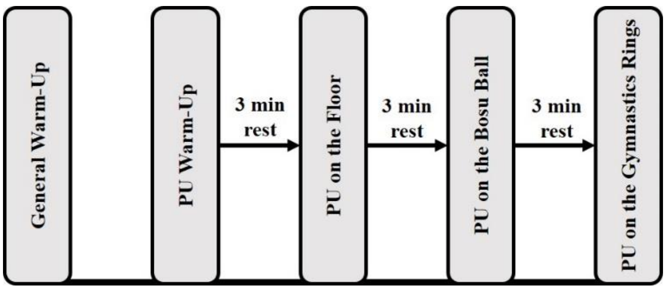

Figure 1. Study design

Purpose of the Research: The aim of this study was to compare muscle activations in PM and TB muscles during PU exercises performed on two unstable surfaces and a stable surface.

Research Group: Nineteen male volunteers (age: 20.89 ± 1.33 years; height: 176.26 ± 6.04 cm; body weight: 72.80 ± 9.94 kg; body fat: 12.79 ± 6.17 %) participated in this study. Male individuals who had performed PU exercises before and had no injuries were included in this study. Female individuals were excluded from this study, male individuals who had not performed PU exercises before and had any injuries were excluded from this study. Prior to the measurements, subjects were warned not to take caffeine or any other stimulant.

Data Collection: The exercise with which the subjects will begin to study was randomly determined by dividing them into three conditions. Before starting the study, subjects were met with information about the study. The subjects performed trials of the exercises on different surfaces before the study. Subjects were given 1-week rest after the trials. During the study, measurements were taken for each individual in 2 sessions on different days in total. Subjects' height, weight, and body composition measurements were made in the morning in the first session. The muscle activation measurements of the subjects were made in the second session. Subjects performed exercises with a 3-minute rest interval. Each subject in the study took place under three conditions.

Procedures

Warm-Up: Subjects performed 5 minutes of running at moderate intensity and 2 minutes of walking before PU exercises. Then subjects performed 5 repetitions of PU on the floor as a warm-up. The subjects rested for 3 minutes after the warm-up protocol.

PU Exercise: In this study, subjects performed the PU exercises on three different surfaces. Subjects started the PU with elbows fully extended, hands placed directly under the shoulder with shoulder-width apart. Hand position was kept the same in all conditions. The distance between the feet was set to 50 cm. The PU exercise was performed in 2 phases. The first phase was descending; in which subjects lowered the body to ~90° elbow flexion. The second phase was ascending; in which subjects raised the body to full elbow extension.

Each phase lasted 2 seconds. Subjects performed PU exercise with full knee extension. Subjects performed 2 sets and 5 repetitions of PU on all surfaces. A 3-minute rest was given to subjects between sets and surface changes. Subjects performed PU exercises on 3 different surfaces:

1. Floor: Subjects performed PU exercise on the floor.

2. Bosu Ball: Subjects performed PU exercise on the Bosu ball. The height of the feet from the ground is adjusted as in the floor condition.

3. Gymnastics Rings: Subjects performed PU exercise on the gymnastics rings. The height of the feet from the ground is adjusted as in the floor condition.

The floor is used as a stable surface. The Bosu ball and gymnastics rings are used as unstable surfaces. PU exercises are shown in Figure 2.

Figure 2. PU exercises. A: Floor; B:Bosu Ball; C: Gymnastics Rings.

Anthropometric Measurements: The Seca 213 stadiometer was used to measure the subjects' body height. Body weight and body composition were measured by using the Tanita BC-418. All measurements were made with the subjects wearing shorts and t-shirts and barefoot.

Electromyography Measurements: Delsys Trigno 4 channel surface electromyography (EMG) device was used for muscle activation measurements. Before placing the electrode on the surface, the area was shaved and cleaned with alcohol. All data were collected at a signal bandwidth of 20-450 Hz with a rectangular pre-magnified bipolar Ag/AgCl surface electrode (Delsys Inc., Boston, MA, USA). The raw EMG signals were sampled at 1926 Hz. EMG activity was recorded from the PM and TB muscles using wireless surface EMG sensors. Electrodes for PM were placed as described by Schick et al. (2010) and for TB as described by Lauver et al. (2016). The subjects performed 2 MVIC for the PM and TB muscles for normalization of the EMG signals. The MVIC tests were carried out as stated by Snarr and Esco (2013). The subjects laid the floor in the prone position and took the PU position with 90° elbow flexion for MVIC of PM. Then subjects attempted the perform PU while the researcher applied the resistance on the subjects' upper back. The subjects positioned their elbow with 90° elbow flexion for MVIC of TB. They attempted the extend their elbow against the resistance. Each MVIC test lasted 5 seconds. After subtracting the first and last 1 second of each MVIC data, the remaining 3 seconds in the middle were used. The average of 2 trials was used in amplitude analysis.

EMG Data Analysis: Root mean square (RMS) values were used for analysis. After removing the largest and smallest values of 5 repetitions, the remaining 3 RMS data were used in amplitude analysis. RMS values of 3 repetitions normalized by using MVIC data. The average of 3 peak amplitude values was used in statistical analysis. This mean activity was expressed as a percentage of the peak activity obtained from the MVIC test for each muscle. All data analysis was performed by using the Delsys EMGworks Analysis software (Delsys, Boston, MA, USA).

Statistical Analysis: The SPSS 25 was used for all statistical analyses. The dependent variables were muscle activations of PM and TB in this study. The independent variables were the stable and unstable surfaces in this study. The normality of data was determined by using the Shapiro-Wilk test. A one-way repeated-measures analysis of variance was used to compare the muscle activity of the conditions. Bonferroni post hoc test was used to determine the significant main effects. The Greenhouse-Geisser correction was used if Mauchly's test of sphericity was significant. The partial eta squared (η_p^2) was computed for the effect sizes. The statistical significance level was set at $p< 0.05$.

RESULTS

Table 1: Normalized EMG (%MVIC) activities of muscles during PU (mean ± standard deviation).

Muscles	Floor	Bosu Ball	Gymnastics Rings	p
Pectoralis Major	75.72 ± 19.78	75.53 ± 25.19	114.04 ± 36.85*	0.000
Triceps Brachii	89.93 ± 31.25	88.84 ± 26.83	86.18 ± 27.06	0.495

**Significant difference according to floor and Bosu ball(p<0.001).*

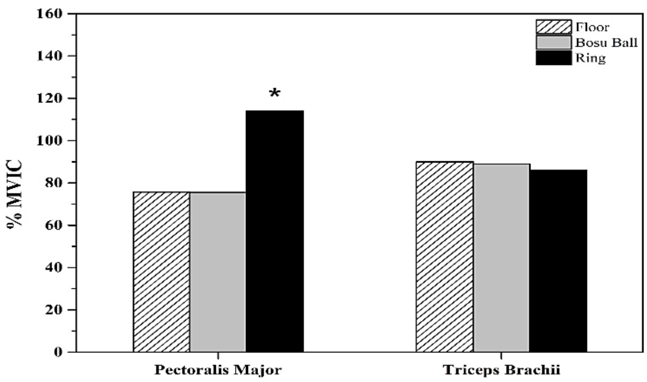

Figure 3: Differences in normalized muscle activities of PM and TB for different surfaces.
**Significantly different from Floor and Bosu ball (p<0.001).*

According to the results of the one-way repeated-measures analysis of variance, a significant difference was found between the conditions ($F=25.820$ $p=0.000$, $\eta_p^2=0.589$) for the muscle activation of PM. PM muscle activation was found to be significantly greater in the gymnastics rings than on the other surfaces ($p<0.001$). No significant difference was determined between the floor and the Bosu ball ($p>0.05$) (Table 1).

No significant difference was found between the conditions for the muscle activation of TB ($F=0.636$, $p=0.495$, $\eta_p^2=0.034$).

DISCUSSION

This study aimed to compare the muscle activation of PM and TB during PU exercise on stable and unstable surfaces. The results showed that PU performed on the gymnastics rings, one of the unstable surfaces, provided a significant increase in muscle activity of the PM compared to both the unstable Bosu ball and the stable floor. When the stable floor and the unstable Bosu ball were compared, no significant difference was found in PM muscle activation. Besides, no significant difference was observed between all surfaces in muscle activation of TB.

These results indicate that performed PU on the gymnastics rings apparatus may be more increased the PM muscle activation. There are studies examining the activity of selected muscles in exercises performed using different stable and unstable surfaces (Anderson et al., 2013; de Araújo et al., 2018; de Araújo et al., 2020; Freeman et al., 2006; Gioftsos et al., 2016; Lehman et al., 2006; Marshall & Murphy, 2006b; McGill et al., 2014; Snarr & Esco, 2013). Besides, there are studies reported that PU exercise performed on suspension causes an enhancement in muscle activation on the upper body muscles such as PM, TB, anterior deltoid (AD), serratus anterior (SA), upper trapezius (UT) (Borreani et al., 2015a; Borreani et al., 2015b; Calatayud et al., 2014a; Calatayud et al., 2014b; Calatayud et al., 2014c; Snarr & Esco, 2013). The results of these studies are consistent with our results of PM muscle activation on the gymnastics rings. Anderson et al. (2013) reported that an increase in muscle activation occurred in parallel with the increase in the level of imbalance in PU movements performed with the balance ball and balance board with standard, single, and dual instability conditions. In the standard conditions participant placed their hands and feet on the floor, in the single instability participants placed their hands or feet on an unstable surface, and in the dual instability conditions participants placed their both hands and feet on an unstable surface. In another study parallel to our study results, Park and Yoo (2013) found that the PU movement performed by healthy amateur badminton players on the uneven surface of the wobble board produced significant EMG muscle activation in the PM muscle compared to a stable surface. The highest vertebral joint compression forces are achieved during suspended push-ups (Dhahbi et al., 2022). Kang et al. (2019) reported that the performing PU plus exercise on an unstable surface may lead to greater muscle activity for the upper trapezius but not for the serratus anterior. Kowalski et al. (2022) stated that the performing PU on unstable surface results in increasing muscle activity for PM, TB, SA and UT comparing the standart PU. Besides they reported that the using suspension device is good option for TB and SA muscles.

It was determined that PU movement did not provide a significant increase in PM and TB muscle activation on the Bosu ball, which is one of the unstable surfaces used in our study. Freeman et al. (2006) found no significant difference in the activation of PM and TB muscles in their study on stable and unstable surfaces. Lehman et al. (2006) had the subjects perform PU exercises by placing the feet or hands separately on the Swiss ball. As a result of their study, they concluded that muscle activation of PM was not affected by surface stability. However, they reported an increase in TB muscle activation PU performed hands on the Swiss ball. Torres et al. (2017) found no significant difference in TB muscle activation after fixed and unsteady PU plus movement. These PM muscle activation results showed parallelism with the results of PU movement EMG muscle activation performed on the floor and Bosu ball in our study. There are also studies that are inconsistent with these results. The stability ball and extreme balance board, which are some of the other unstable surfaces, have been reported to be effective on core stabilizers, TB, and soleus muscle activations (Anderson et al., 2013). In addition, the Swiss Ball is effective to increase muscle activation together with the exercises performed for PM, AD, and TB (Marshall & Murphy, 2006a; Marshall & Murphy, 2006b). Sandhu et al. (2008) reported significant increases in PM and TB muscle activity only during the eccentric phase of elbow push-ups after PU movement with the Swiss ball. As a result, not all muscles are affected similarly by the surface instability changing (de Oliveira et al., 2008; Anders et al., 2004; Norwood et al., 2007) and the responses may be linked to stabilizing or activating muscles (Gibbons & Comerford, 2001; Mottram & Comerford, 1998). This suggests that different unstable surfaces and different PU variations may also elicit different muscle activations. Each joint actively involved in the PU movement has only one degree of freedom to function up and down. The loop tool suspended above reduces the support base for the upper body. Due to this imbalance, the body struggles to prevent unwanted movements that can be made in different directions (Lander et al., 1985; McCaw & Friday, 1994). Hands placed in the gymnastics rings provide greater degrees of freedom than stable ground placement. With additional intervals of freedom, more motor units are engaged to perform a given exercise, leading to an increase in EMG output (Beach et al., 2008; Snarr & Esco, 2013; Wahl & Behm, 2008). A similar situation was observed in the chest press movement performed with free and non-free weights (Behm, 1995; Saeterbakken et al., 2011). The study results show that PU exercises performed on the gymnastics rings induced greater muscle activation of PM compared to the floor and Bosu ball. Muscle activation of TB was not influenced by surface stability in PU.

The present study had some limitations. First, only males took part in this study. Second, muscle activities of PM and TB investigated. Third, the single instability conditions (only hands on unstable surfaces) were compared.

Suggestions: PU exercise is widely used to improve PM muscle strength. This exercise could be performed in different variations and also on different surfaces. According to our study results, PM muscle activation in the gymnastics rings was found to be greater than in the Bosu ball and the stable floor. However, it was observed that TB muscle activation is similar on the 3 surfaces. Thus gymnastics rings apparatus could be used to improve PM muscle activation during PU exercise. Athletes and coaches could implement gymnastics rings as an apparatus instead of a stable surface or bosu ball in their strength training programs to perform PU exercises for greater PM muscle activity. However, they could use stable surface, Bosu ball or gymnastics rings for TB.

Ethics: *In this article, during the research process, journal writing rules, publication principles, research and publication ethics rules, and journal ethics rules were followed. Responsibility for any violations that may arise regarding the article belongs to the author. The Hitit University non-interventional research ethics committee approved the study (Ethics Decision Number: 2022-28).*

Conflict of Interest*: The authors state that there is no personal or financial conflict of interest.*

Author Contribution Rate: *While the contribution rate of the first author in this study is 50%, the total contribution rate of the other authors is 50%.*

References

Anders, C., Bretschneider, S., Bernsdorf, A., Erler, K., & Schneider, W. (2004). Activation of shoulder muscles in healthy men and women under isometric conditions. Journal of Electromyography and Kinesiology, 14(6), 699-707. https://doi.org/10.1016/j.jelekin.2004.04.003

Anderson, K.G., & Behm, D.G. (2004). Maintenance of EMG activity and loss of force output with instability. Journal of Strength & Conditioning Research, 18(3), 637-640.

Anderson, G.S., Gaetz, M., Holzmann, M., & Twist, P. (2013). Comparison of EMG activity during stable and unstable push-up protocols. European Journal of Sport Science, 13(1), 42-48. https://doi.org/10.1080/17461391.2011.577240

Ashnagar, Z., Shadmehr, A., Hadian, M., Talebian, S., & Jalaei, S. (2016). The effects of whole body vibration on EMG activity of the upper extremity muscles in static modified push up position. Journal of Back and Musculoskeletal Rehabilitation, 29(3), 557-563. https://doi.org/10.3233/BMR-160657

Batbayar, Y., Uga, D., Nakazawa, R., & Sakamoto, M. (2015). Effect of various hand position widths on scapular stabilizing muscles during the push-up plus exercise in healthy people. Journal of Physical Therapy Science, 27(8), 2573-2576. https://doi.org/10.1589/jpts.27.2573

Beach, T.A., Howarth, S.J., & Callaghan, J.P. (2008). Muscular contribution to low-back loading and stiffness during standard and suspended push-ups. Human Movement Science, 27(3), 457-472. https://doi.org/10.1016/j.humov.2007.12.002

Behm, D.G. (1995). Neuromuscular implications and applications of resistance training. Journal of Strength & Conditioning Research, 9(4), 264-274.

Behm, D.G., Leonard, A.M., Young, W.B., Bonsey, W.A., & MacKinnon, S.N. (2005). Trunk muscle electromyographic activity with unstable and unilateral exercises. Journal of Strength & Conditioning Research, 19(1), 193-201.

Behm, D.G., & Anderson, K.G. (2006). The role of instability with resistance training. Journal of Strength & Conditioning Research, 20(3), 716-722.

Borreani, S., Calatayud, J., Colado, J.C., Tella, V., Moya-Nájera, D., Martin, F., et al. (2015a). Shoulder muscle activation during stable and suspended push-ups at different heights in healthy subjects. Physical Therapy in Sport, 16(3), 248-254. https://doi.org/10.1016/j.ptsp.2014.12.004

Borreani, S., Calatayud, J., Colado, J.C., Moya-Nájera, D., Triplett, N.T., & Martin, F. (2015b). Muscle activation during push-ups performed under stable and unstable conditions. Journal of Exercise Science & Fitness, 13(2), 94-98. https://doi.org/10.1016/j.jesf.2015.07.002

Burden, A., & Bartlett, R. (1999). Normalisation of EMG amplitude: an evaluation and comparison of old and new methods. Medical Engineering & Physics, 21(4), 247-257. https://doi.org/10.1016/S1350-4533(99)00054-5

Calatayud, J., Borreani, S., Colado, J., Martin, F., Batalha, N., & Silva, A. (2014a). Muscle activation differences between stable push-ups and push-ups with an unilateral v-shaped suspension system at different heights. Motricidade 10(4), 84-93. http://dx.doi.org/10.6063/motricidade.10(4).3395

Calatayud, J., Borreani, S., Colado, J.C., Martín, F.F., Rogers, M.E., Behm, D.G., & Andersen, L.L. (2014b). Muscle activation during push-ups with different suspension training systems. Journal of Sports Science & Medicine, 13(3), 502-510.

Calatayud, J., Borreani, S., Colado, J.C., Martin, F., & Rogers, M.E. (2014c). Muscle activity levels in upper-body push exercises with different loads and stability conditions. The Physician and Sportsmedicine, 42(4), 106-119. https://doi.org/10.3810/psm.2014.11.2097

Cho, S.H., Baek, I.H., Cheon, J.Y., Cho, M.J., Choi, M.Y., & Jung, D.H. (2014). Effect of the push-up plus (PUP) exercise at different shoulder rotation angles on shoulder muscle activities. Journal of Physical Therapy Science, 26(11), 1737-1740. https://doi.org/10.1589/jpts.26.1737

Cogley, R.M., Archambault, T.A., Fibeger, J.F., & Koverman, M.M. (2005). Comparison of muscle activation using various hand positions during the push-up exercise. The Journal of Strength & Conditioning Research, 19(3), 628-633.

de Araújo, R.C., Pirauá, A.L.T.., Beltrão, N.B., & Pitangui, A.C.R. (2018). Activity of periscapular muscles and its correlation with external oblique during push-up: Does scapular dyskinesis change the electromyographic response?. Journal of Sports Sciences, 36(5), 571-577. https://doi.org/10.1080/02640414.2017.1324205

de Araújo, R.C., Nascimento, V.Y.S., Torres, R.J.B., Trombini-Souza, F., Behm, D., & Pitangui, A.C.R. (2020). Can the use of unstable surfaces and instruction for conscious abdominal contraction increase the EMG activity of the periscapular muscles during the dynamic push-up?. Journal of Sport Rehabilitation, 29(2), 225-230. https://doi.org/10.1123/jsr.2018-0165

De Luca, C. J. (1997). The use of surface electromyography in biomechanics. Journal of Applied Biomechanics, 13(2), 135-163.

de Oliveira, A.S., de Morais Carvalho, M., & de Brum, D.P.C. (2008). Activation of the shoulder and arm muscles during axial load exercises on a stable base of support and on a medicine ball. Journal of Electromyography and Kinesiology, 18(3), 472-479. https://doi.org/10.1016/j.jelekin.2006.09.009

Dhahbi, W., Chaabene, H., Chaouachi, A., Padulo, J., G Behm, D., Cochrane, J., et al. (2022). Kinetic analysis of push-up exercises: a systematic review with practical recommendations. Sports biomechanics, 21(1), 1-40. https://doi.org/10.1080/14763141.2018.1512149

Freeman, S., Karpowicz, A., Gray, J., & McGill, S. (2006). Quantifying muscle patterns and spine load during various forms of the push-up. Medicine and Science in Sports and Exercise, 38(3), 570-577. https://doi.org/10.1249/01.mss.0000189317.08635.1b

Gibbons, S.G., & Comerford, M.J. (2001). Strength versus stability part 1; concept and terms. Orthopaedic Division Review, 43(1), 21-27.

Gioftsos, G., Arvanitidis, M., Tsimouris, D., Kanellopoulos, A., Paras, G., Trigkas, P., et al. (2016). EMG activity of the serratus anterior and trapezius muscles during the different phases of the push-up plus exercise on different support surfaces and different hand positions. Journal of Physical Therapy Science, 28(7), 2114-2118. https://doi.org/10.1589/jpts.28.2114

Grațiela-Flavia, D., Flavia, R., & Emilia, G. (2009). Surface electromyography in biomechanics: applications and signal analysis aspects. Journal of Physical Education & Sport/Citius Altius Fortius, 25(4), 56-65.

Kang, D.H., Jung, S.Y., Nam, D.H., Shin, S.J., & Yoo, W.G. (2014). The effects of push-ups with the trunk flexed on the shoulder and trunk muscles. Journal of Physical Therapy Science, 26(6), 909-910. https://doi.org/10.1589/jpts.26.909

Kang, F. J., Ou, H. L., Lin, K. Y., & Lin, J. J. (2019). Serratus anterior and upper trapezius electromyographic analysis of the push-up plus exercise: a systematic review and meta-analysis. Journal of Athletic Training, 54(11), 1156-1164. https://doi.org/10.4085/1062-6050-237-18

Kim, S.H., Kwon, O.Y., Kim, S.J., Park, K.N., Choung, S.D., & Weon, J.H. (2014). Serratus anterior muscle activation during knee push-up plus exercise performed on static stable, static unstable, and oscillating unstable surfaces in healthy subjects. Physical Therapy in Sport, 15(1), 20-25. https://doi.org/10.1016/j.ptsp.2013.01.001

Kowalski, K.L., Connelly, D.M., Jakobi, J.M., & Sadi, J. (2022). Shoulder electromyography activity during push-up variations: a scoping review. Shoulder & Elbow, 14(3), 325-339. https://doi.org/10.1177/1758573221101937

Lander, J.E., Bates, B.T., Sawhill, J.A., & Hamill, J.A. (1985). A comparison between free-weight and isokinetic bench pressing. Medicine and Science in Sports and Exercise, 17(3), 344-353.

Lauver, J.D., Cayot, T.E., & Scheuermann, B.W. (2016). Influence of bench angle on upper extremity muscular activation during bench press exercise. European Journal of Sport Science, 6(3), 309-316. https://doi.org/10.1080/17461391.2015.1022605

Lee, S., Lee, D., & Park, J. (2013). The effect of hand position changes on electromyographic activity of shoulder stabilizers during push-up plus exercise on stable and unstable surfaces. Journal of Physical Therapy Science, 25(8), 981-984. https://doi.org/10.1589/jpts.25.981

Lehman, G.J., MacMillan, B., MacIntyre, I., Chivers, M., & Fluter, M. (2006). Shoulder muscle EMG activity during push up variations on and off a Swiss ball. Dynamic Medicine, 5(1), 1-7.

Ludewig, P.M., Phadke, V., Braman, J.P., Hassett, D. R., Cieminski, C.J., & LaPrade, R.F. (2009). Motion of the shoulder complex during multiplanar humeral elevation. The Journal of Bone and Joint Surgery, 91(2), 378-389. https://doi.org/10.2106/JBJS.G.01483

Marshall, P.W., & Murphy, B.A. (2005). Core stability exercises on and off a Swiss ball. Archives of Physical Medicine and Rehabilitation, 86(2), 242-249. https://doi.org/10.1016/j.apmr.2004.05.004

Marshall, P., & Murphy, B. (2006a). Changes in muscle activity and perceived exertion during exercises performed on a swiss ball. Applied Physiology, Nutrition, and Metabolism, 31(4), 376-383. https://doi.org/10.1139/h06-006

Marshall, P.W., & Murphy, B.A. (2006b). Increased deltoid and abdominal muscle activity during Swiss ball bench press. Journal of Strength & Conditioning Research, 20(4), 745-750.

McCaw, S.T., & Friday, J.J. (1994). A comparison of muscle activity between a free weight and machine bench press. Journal of Strength & Conditioning Research, 8(4), 259-264.

McGill, S.M., Cannon, J., & Andersen, J.T. (2014). Analysis of pushing exercises: Muscle activity and spine load while contrasting techniques on stable surfaces with a labile suspension strap training system. The Journal of Strength & Conditioning Research, 28(1), 105-116. https://doi.org/10.1519/JSC.0b013e3182a99459

Mottram, S., & Comerford, M. (1998). Stability dysfunction and low back pain. Journal of Orthopaedic Medicine, 20(2), 13-18. https://doi.org/10.1080/1355297X.1998.11719881

Naughton, J., Adams, R., & Maher, C. (2005). Upper-body wobbleboard training effects on the post-dislocation shoulder. Physical Therapy in Sport, 6(1), 31-37. https://doi.org/10.1016/j.ptsp.2004.05.005

Norcross, M. F., Blackburn, J. T., & Goerger, B. M. (2010). Reliability and interpretation of single leg stance and maximum voluntary isometric contraction methods of electromyography normalization. Journal of Electromyography and Kinesiology, 20(3), 420-425. https://doi.org/10.1016/j.jelekin.2009.08.003

Norwood, J.T., Anderson, G.S.., Gaetz, M.B., & Twist, P.W. (2007). Electromyographic activity of the trunk stabilizers during stable and unstable bench press. Journal of Strength & Conditioning Research, 21(2), 343-347.

Park, S.Y., & Yoo, W.G. (2013). Effects of push-up exercise phase and surface stability on activation of the scapulothoracic musculature. Journal of Athletic Therapy and Training, 18(4), 34-38. https://doi.org/10.1123/ijatt.18.4.34

Park, K.M., Cynn, H.S., Kwon, O.Y., Yi, C.H., Yoon, T.L., & Lee, J.H. (2014). Comparison of pectoralis major and serratus anterior muscle activities during different push-up plus exercises in subjects with and without scapular winging. The Journal of Strength & Conditioning Research, 28(9), 2546-2551. https://doi.org/10.1519/JSC.0000000000000443

Pirauá, A.L.T., Pitangui, A.C.R., Silva, J.P., dos Passos, M.H.P., de Oliveira, V.M.A., Batista, L.D.S.P., et al. (2014). Electromyographic analysis of the serratus anterior and trapezius muscles during push-ups on stable and unstable bases in subjects with scapular dyskinesis. Journal of Electromyography and Kinesiology, 24(5), 675-681. https://doi.org/10.1016/j.jelekin.2014.05.009

Rainoldi, A., Melchiorri, G., & Caruso, I. (2004). A method for positioning electrodes during surface EMG recordings in lower limb muscles. Journal of Neuroscience Methods, 134(1), 37-43. https://doi.org/10.1016/j.jneumeth.2003.10.014

Saeterbakken, A.H., van den Tillaar, R., & Fimland, M.S. (2011). A comparison of muscle activity and 1-RM strength of three chest-press exercises with different stability requirements. Journal of Sports Sciences, 29(5), 533-538. https://doi.org/10.1080/02640414.2010.543916

Sandhu, J.S., Mahajan, S., & Shenoy, S. (2008). An electromyographic analysis of shoulder muscle activation during push-up variations on stable and labile surfaces. International journal of Shoulder Surgery, 2(2), 30-35. https://doi.org/10.4103/0973-6042.40456

Schick, E.E., Coburn, J.W., Brown, L.E., Judelson, D.A., Khamoui, A.V., Tran, T.T., et al. (2010). A comparison of muscle activation between a Smith machine and free weight bench press. The Journal of Strength & Conditioning Research, 24(3), 779-784. https://doi.org/10.1519/JSC.0b013e3181cc2237

Snarr, R.L., & Esco, M.R. (2013). Electromyographic comparison of traditional and suspension push-ups. Journal of Human Kinetics, 39(1), 75-83. https://doi.org/10.2478/hukin-2013-0070

Steckey, P. (2004). Progressive uses of the Bosu™ balance trainer. Journal of Athletic Therapy and Training, 9(1), 60-61. https://doi.org/10.1123/att.9.1.60

Torres, R.J., Pirauá, A.L.T., Nascimento, V.Y., Dos Santos, P.S., Beltrão, N.B., de Oliveira, V.M., et al. (2017). Shoulder muscle activation levels during the push-up-plus exercise on stable and unstable surfaces. Journal of Sport Rehabilitation,26(4), 281-286, 2017. https://doi.org/10.1123/jsr.2016-0050

Tucker, W.S., Armstrong, C.W., Gribble, P.A., Timmons, M.K., & Yeasting, R.A. (2010). Scapular muscle activity in overhead athletes with symptoms of secondary shoulder impingement during closed chain exercises. Archives of Physical Medicine and Rehabilitation, 91(4), 550-556. https://doi.org/10.1016/j.apmr.2009.12.021

Vera-Garcia, F.J., Grenier, S.G., & McGill, S.M. (2000). Abdominal muscle response during curl-ups on both stable and labile surfaces. Physical Therapy, 80(6), 564-569. https://doi.org/10.1093/ptj/80.6.564

Wahl, M.J., & Behm, D.G. (2008). Not all instability training devices enhance muscle activation in highly resistance-trained individuals. Journal of Strength & Conditioning Research, 22(4), 1360-1370. https://doi.org/10.1519/JSC.0b013e318175ca3c

GENİŞLETİLMİŞ ÖZET

Çalışmanın Amacı: Bu çalışmanın amacı, stabil ve stabil olmayan yüzeylerde gerçekleştirlien şınav PU egzersizi sırasında pektoralis major (PM) ve triceps brachii (TB) kaslarının kas aktivasyonlarını karşılaştırmaktır.

Araştırma Soruları: Stabil ve stabil olmayan yüzeylerde gerçekleştirlen şınav egzersizlerinde pectoralis major kas aktivasyonunda fark var mıdır?

Stabil ve stabil olmayan yüzeylerde gerçekleştirlen şınav egzersizlerinde triceps brachii kas aktivasyonunda fark var mıdır?

Literatur Araştırması: Bosu topu, TRX gibi stabil olmayan yüzeyler kuvvet antrenmanlarında performansı artırmak için sıkça kullanılmaktadır. Stabil olmayan yüzey egzersizleri, nöromüsküler sistemin vücudun eklemlerini ve kaslarını stabilize etme talebini artırarak daha fazla kas aktivasyonuna neden olur (Lehman et al., 2006). Stabil olmayan yüzeylerin gövde kas aktivitesi üzerindeki etkisini araştıran birçok çalışma mevcuttur. Egzersiz topu üzerinde oturarak yapılan üst vücut egzersizlerinde gövde kas aktivasyonunun arttığı belirtilmiştir (Behm, 2005). Anderson ve Behm (2004), stabil olmayan bir yüzey kullanmanın, aynı miktarda kuvvet oluşturmak için stabil bir yüzeye göre daha fazla kas

aktivasyonu gerektirdiğini öne sürmektedir. Şınav egzersizi yaygın olarak kullanılan bir egzersizdir. Bu egzersiz özellikle pektoralis major, triceps brachii (Ashnagar et al., 2016; Calatayud et al., 2014a; Cogley et al., 2005; Freeman et al., 2006; Marshall & Murphy, 2005; Snarr & Esco, 2013), serratus anterior ve trapezius (Ashnagar et al., 2016; de Araújo et al., 2020; Ludewig et al., 2009; Tucker et al., 2010) kaslarının aktivasyonu için önemlidir. Şınav egzersizinin birçok varyasyonu vardır. Bunlardan bir tanesi de dış çevre stabilizasyonu değiştirilerek sağlanabilir.

Yöntem: Bu çalışmada çapraz deney deseni kullanılmıştır. Bu çalışmaya 19 erkek gönüllü (yaş: 20.89 ± 1.33 yıl; boy: 176.26 ± 6.04 cm; vücut ağırlığı: 72.80 ± 9.94 kg; vücut yağı: % 12.79 ± 6.17) katılmıştır. Katılımcılar, çalışmadan önce farklı yüzeylerde egzersizlerin denemelerini yapmışlardır. Denemelerden sonra katılımcılar rastgele olarak üç yüzeyden birisinde çalışmaya başlamışlardır. Çalışmanın birinci oturumunda katılımcıların boy uzunlukları, vücut ağırlıkları ve vücut yağ yüzdeleri ölçülmüştür. İkinci oturumda ise katılımcılar farklı yüzeylerde şınav egzersizlerini gerçekleştirmişlerdir. Egzersiz gününde katılımcılar çalışmaya 5 dakikalık orta şiddette koşu ve ardından 2 dakikalık yürüyüş ile ısınma gerçekleştirerek başlamışlarıdır. Daha sonra yerde 5 şınav yaparak ısınma yapmışlardır. Isınmadan sonra 3 dakika dinenme verilmiştir. Şınav egzersizi her bir yüzeyde 2 set ve her set 5 tekrar olarak yapılmıştır. Setler arasında ve yüzey değişimlerinde katılımcılar 3 dakika dinlenmişlerdir. Şınav egzersizleri stabil yüzey olarak yerde ve stabil olmayan yüzey olarak cimnastik halkası ve Bosu topunda gerçekleştirilmiştir. Kas aktivasyon ölçümleri için Delsys Trigno 4 kanallı yüzey elektromiyografi (EMG) cihazı kullanılmıştır. EMG aktivitesi, kablosuz yüzeysel EMG sensörleri kullanılarak pectoralis majör ve triceps brachii kaslarından bilateral olarak kaydedeilmiştir. Analiz için root mean square (RMS) değerleri kullanılmıştır. Elde edilen veriler maksimum istemli izometrik kasılma (maximum voluntary isometric contraction (MVIC)) verilerine normalize edilmiştir. Verilerin normalliğini belirlemek için Shapiro-Wilk testi kullanılmıştır. Yüzeyler arasındaki kas aktivitesi farklılıklarnı belirlemek için tekrarlı ölçümlerde tek yönlü varyans analizi kullanılmıştır.

Sonuç ve Değerlendirme: Bu çalışma sonucunda, stabil olmayan yüzeylerden biri olan halka üzerinde gerçekleştirilen şınav egzersizinin, hem stabil olmayan bir diğer yüzey Bosu topuna hem de stabil yüzeye kıyasla pectoralis major kas aktivasyonunda önemli bir artış sağladığı bulunmuştur. Ancak Bosu topu ile stabil yüzey arasında bir fark bulunmamıştır. Ayrıca triceps brachii kas aktivasyonunda yüzeyler arasında bir fark saptanmamıştır.