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Shoulder muscle activation during stable and suspended push-ups at different heights in healthy subjects

Sebastien Borreani [a], Joaquin Calatayud [a], Juan C. Colado [a,*], Victor Tella [a], Diego Moya-Nájera [a], Fernando Martin [a], Michael E. Rogers [b]

[a] Research Group in Sport and Health, Department of Physical Education and Sports, University of Valencia, Valencia, Spain
[b] Department of Human Performance Studies, Wichita State University, Wichita, KS, USA

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ABSTRACT

Objectives: To analyze shoulder muscle activation when performing push-ups under different stability conditions and heights.
Study design: Comparative study by repeated measures.
Setting: Valencia University laboratory.
Participants: 29 healthy males participated.
Main outcome measures: Subjects performed 3 push-ups each with their hands at 2 different heights (10 vs. 65 cm) under stable conditions and using a suspension device. Push-up speed was controlled and the testing order was randomized. The average amplitudes of the electromyographic root mean square of the long head of the triceps brachii (TRICEP), upper trapezius (TRAPS), anterior deltoid (DELT) and clavicular pectoralis (PEC) were recorded. The electromyographic signals were normalized to the maximum voluntary isometric contraction (MVIC).
Results: Suspended push-ups at 10 cm resulted in greater activation in the TRICEP (17.14 ± 1.31 %MVIC vs. 37.03 ± 1.80 %MVIC) and TRAPS (5.83 ± 0.58 %MVIC vs. 14.69 ± 1.91 %MVIC) than those performed on the floor. For DELT and PEC similar or higher activation was found performing the push-ups on the floor, respectively. Height determines different muscle activation patterns.
Conclusions: Stable push-ups elicit similar PEC and higher DELT muscle activation, being greater at 10 cm; whereas suspended push-ups elicit greater TRAPS and TRICEP muscle activation, being greater at 65 cm.

1. Introduction

In recent years, an increased number of unstable training devices have emerged, although popularity is not always equated with effectiveness (Behm & Colado, 2012). The use of unstable devices involves the performance of an exercise in an unstable environment while the resistance is provided by body mass or through an external resistance (Behm & Colado, 2012). Suspension training is a way to perform an exercise under an unstable environment with body weight leveraging gravity. Currently, suspension training devices are popular training systems and their use is growing in fitness, sport and rehabilitation settings as they appear to provide a better training stimulus compared to traditional stable conditions (Behm & Colado, 2012). However, there is a lack of scientific knowledge regarding suspension devices. Coaches would benefit from an understanding of suspension devices so as to better design functional movements that can improve athletic performance (Behm & Colado, 2012) and physiotherapists would benefit from knowledge regarding muscle activation during suspension training which could improve rehabilitation protocols (de Oliveira, de Morais Carvalho, & de Brum, 2008). Thus, suspension devices could be effective for both athletic performance and rehabilitation but an understanding of the specific effects of such exercise is relatively unknown (Beach, Howarth, & Callaghan, 2008; Behm & Colado, 2012).

The shoulder complex in particular accounts for a considerable proportion of injuries and several upper extremity prevention and

* Corresponding author. Universidad de Valencia (FCAFE), Aulario Multiusos, C/ Gasco Oliag, 3, 46010 Valencia, Spain. Tel.: +34 667507636; fax: +34 963 864 353.
E-mail address: juan.colado@uv.es (J.C. Colado).

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conditioning programs emphasize large muscles. That produces obvious gains in strength and hypertrophy, subsequently neglecting the smaller muscles responsible for stabilization. This biased exercise selection creates joint and muscle imbalances, and may place participants at-risk for injury (Kim, Kwon, Kim, Park, Choung, & Weon, 2014; Kolber, Beekhuizen, Cheng, & Hellman, 2010). Traditional and unstable push-ups have been used for years to improve muscle performance/rehabilitation of the shoulder musculature (Youdas, Budach, Ellerbusch, Stucky, Wait, & Hollman, 2010). One of the exercises that can be performed with these new suspension devices is the push-up. While recent push-ups studies were mainly conducted to compare the muscle activity during a stable condition and the same exercise performed on unstable devices such as on a Swiss ball (Lehman, MacMillan, MacIntyre, Chivers, & Fluter, 2006) or on two basketball balls (Freeman, Karpowicz, Gray, & McGill, 2006), suspended push-ups remain poorly investigated. In fact, to the best of our knowledge, there are only a few recent papers that focused on suspended push-ups performed with standard technique (Beach et al., 2008; Snarr & Esco, 2013), moreover, information regarding muscle activation performing suspended/stable push-ups at two different heights has not been widely reported previously or comparison between stabilizer and mobilizer muscles of the shoulder. Thus, our purpose was to determine the muscle activation on some mobilizer and stabilizer muscles of the shoulder associated with this type of suspension device during a push-up compared with a stable push-up at two different heights (i.e. hands at 10 and 65 cm from the floor). We hypothesized that suspended push-ups would elicit a superior activation for the long head of triceps brachii and upper trapezius but not for the clavicular pectoralis and the anterior deltoid. We also hypothesized that a lower angle between body and ground (10 cm push-up) would result in greater intensity and therefore would increase muscle activation.

2. Methods

2.1. Subjects

Fit young male university students ($n = 29$; mean ± SD age: 23.5 ± 3.1 years; height: 178.2 ± 5.9 cm; body mass: 75.2 ± 8.5 kg; body fat percentage: 10.0 ± 2.5% and biacromial width: 39.1 ± 1.5 cm) volunteered to take part in this study. The number of subjects chosen was calculated using G Power Software (University of Kiel, Germany) and was based on effect size 0.25 SD with an α level of 0.05 and power at 0.80. Participants had a minimum of 1 year of resistance training, performing at least 2 sessions per week at moderate to vigorous intensity. No participant included in this study presented with musculoskeletal pain, neuromuscular disorders, or any form of joint or bone disease. All subjects signed an institutional informed consent form before starting the protocol, and the institution's review board approved the study. All procedures described in this section comply with the requirements listed in the 1975 Declaration of Helsinki and its amendment in 2008.

2.2. Experimental procedures

Each subject took part in 2 sessions: familiarization and experimental sessions both at the same time in the morning. The first session took place 48–72 h before data collection in the experimental session. Several restrictions were imposed on the volunteers: no food, drinks or stimulants (e.g. caffeine) to be consumed 3–4 h before the sessions and no physical activity more intense than normal daily activities 12 h before the exercises. They were instructed to sleep more than 8 h the night before data collection. All measurements were made by the same investigators during the morning, and the procedures were always conducted in the same facility (with temperature at 20 °C).

During the familiarization session, the participants were familiarized with the stable push-up exercise and the suspended push-up, movement amplitude, body position and cadence of movement that would later be used during data collection. Participants practiced the exercises typically 1–3 times each until the subject felt confident and the researcher was satisfied that the form had been achieved. In addition, height (IP0955, Invicta Plastics Limited, Leicester, England), body mass, body fat percentages (Tanita model BF- 350) and biacromial width were obtained according to the protocols used in previous studies (García-Massó et al., 2011).

The protocol started with the preparation of participants' skin, followed by electrode placement, maximal voluntary isometric contraction (MVIC) collection and performance of the exercise. Hair was removed from the skin overlying the muscles of interest and the skin was then cleaned by rubbing with cotton wool dipped in alcohol for the subsequent electrode placement positioned according to the recommendations (Cram, Kasman, & Holtz, 1998) on the Long Head of the Triceps Brachii (TRICEP), Upper Trapezius (TRAPS), Anterior Deltoid (DELT) and Clavicular Pectoralis (PEC) on the dominant side of the body. Pre-gelled bipolar silver/silver chloride surface electrodes (Blue Sensor M-00-S, Medicotest, Olstykke, DNK) were placed with an interelectrode distance of 25 mm. The reference electrode was placed between the active electrodes, approximately 10 cm away from each muscle, in accordance with the manufacturer's specifications. Once the electrodes were placed, participants performed 2 standard push-ups on the floor in order to check signal saturation. All signals were acquired at a sampling frequency of 1 kHz, amplified and converted from analog to digital. All records of myoelectrical activity were stored on a hard drive for later analysis. A ME6000P8 (Mega Electronics, Ltd., Kuopio, Finland) biosignal conditioner was used to acquire the surface electromyographic (EMG) signals produced during exercise.

Prior to the dynamic exercises described below, two 5 s MVICs were performed for each muscle according to standardized procedures and the trial with the highest EMG was used. 1-minute rest was given between each MVIC and standardized verbal encouragement was provided to motivate all participants to achieve their maximum. Positions for the MVICs were performed according to standardized procedures, chosen based on commonly used muscle testing positions for the TRICEP (Kendall, McCreary, Provance, Rodgers, & Romani, 2005), TRAPS (Ekstrom, Soderberg, & Donatelli, 2005), DELT (Ekstrom et al., 2005) and PEC (Snyder & Fry, 2012), and were performed against a fixed immovable resistance (i.e., Smith machine). Specifically, the MVICs were performed as follows: For the TRICEP, participants performed a forearm extension with elbows at 90° in a seated position an erect posture with no back support. For the TRAPS, participants performed a deltoid abduction at 90° in a seated position an erect posture with no back support. For the DELT, participants performed a deltoid flexion at 90° in a seated position an erect posture with no back support. For the PEC, participants performed a bench press with a grip at 150% of biacromial width, the shoulder abducted at 45° and feet flat on the bench. The participants performed the 3 push-ups under 4 conditions in a random order to reduce threats to the study's internal validity, with 2 min interval between them. Stable and suspension equipment (TRX Suspension Trainer™, TRX®, San Francisco, CA, USA) conditions were performed at 10 cm and 65 cm from the floor (Fig. 1). The suspension device has a main band and on the bottom of this band there is a main carabiner and a stabilizing loop where another band is locked, forming a V with handles on the bottom. The participants started the push-ups in an