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ScienceDirect

Journal of Exercise Science & Fitness 13 (2015) 94–98

www.elsevier.com/locate/jesf

Original article

Muscle activation during push-ups performed under stable and unstable conditions

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Received 17 June 2013; revised 13 May 2015; accepted 14 July 2015
Available online 2 September 2015

Abstract

Background/Objective: The purpose of this study was to analyze muscle activation when performing push-ups under different stability conditions.

Methods: Physically fit young male university students ($N = 30$) performed five push-ups under stable conditions (on the floor) and using four unstable devices (wobble board, stability disc, fitness dome, and the TRX Suspension Trainer). The push-up speed was controlled using a metronome, and the testing order was randomized. The average amplitudes of the electromyographic (EMG) root mean square of the anterior deltoid (DELT), serratus anterior (SERRA), lumbar multifidus (LUMB), and rectus femoris (FEM) were recorded. The electromyographic signals were normalized to the maximum voluntary isometric contraction (MVIC).

Results: No significant differences were found for the DELT [$F(4,112) = 1.978$; $p = 0.130$] among the conditions. However, statistically significant differences were found among the different conditions for the SERRA [$F(4,60) = 17.649$; $p < 0.001$], LUMB [$F(4,76) = 12.334$; $p < 0.001$], and FEM [$F(4,104) = 24.676$; $p < 0.001$] muscle activation. The suspended device was the only condition that elicited higher LUMB and FEM activation compared to the other conditions. Push-ups performed on the floor showed lower SERRA activation than those performed with all unstable devices.

Conclusion: Not all unstable devices enhance muscle activation compared to traditional push-ups.

Keywords: Core; EMG; Instability

Introduction

Push-up exercise is normally used to strengthen the torso or upper body.[1] In contrast to the classic push-up performed on the floor, the use of unstable devices during exercise may lead to the recruitment of different muscle patterns. During the past few years, various unstable devices, such as stability balls or Swiss balls,[2] suspended devices,[3] and basketball balls,[1] have been used to perform the push-up exercise. However, only a few studies have compared the muscle activation using suspension equipment with other typical unstable bases.

The use of unstable devices has been reported to increase the activation of specific muscles compared to a push-up performed on a stable surface.[1–3] Concretely, a significant increase has been reported in the activation of muscles in the abdominal wall during suspended push-ups in comparison with those performed under stable conditions.[3] Furthermore,

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http://dx.doi.org/10.1016/j.jesf.2015.07.002

greater triceps brachii activation during push-ups on a Swiss ball and greater upper trapezius activation during a one-arm maintained push-up on a medicine ball have also been reported.[2,4] On the contrary, for the deltoid, push-ups on the floor showed similar or significantly higher activation in comparison with those performed on unstable surfaces.[2]

Some unstable devices have been investigated during push-ups and were shown to induce higher muscle activation of core stabilizers, prime movers, and lower body stabilizers.[1–5] In addition, dual instability provoked greater muscle activation than single instability or the stable condition.[5] However, it is unknown if suspension equipment leads to greater or smaller muscle activation in comparison to other commonly used unstable devices that can be selected to perform push-ups with unstable bases, such as the stability disc, wobble board, and fitness dome.

Push-up studies usually consider the primary muscles involved in the action as the pectoralis major,[1,2] anterior deltoid,[1,4] and triceps brachii,[1,2,5] although the first two muscles do not seem to be greatly affected by an unstable condition.[1,2] Less is known regarding the effects of performing push-ups with these devices on the recruitment of other stabilizer muscles, such as the rectus femoris and the anterior serratus, or core muscles, such as the lumbar multifidus. Unstable conditions seem to enhance the activation of core muscles, especially when dual instability is compared to single instability.[5] It has been demonstrated that unstable devices can increase muscle activation and that efficient exercises are needed for rehabilitation and athletic conditioning programs,[2,4,6] therefore, the purpose of the present study was to compare the activity levels of the aforementioned muscles during stable push-ups on the floor with push-ups performed using different types of unstable devices (i.e., the stability disc, wobble board, fitness dome and TRX Suspension Trainer).

Increases in the muscle electromyographic (EMG) signal are associated with increases in muscle force or strength output.[6,7] Exercises that produce higher EMG signal amplitudes are assumed to yield greater strengthening effects.[8,9] Hence, changes in muscle activation would be associated with changes in muscle force output. We hypothesized that the use of unstable devices would significantly increase the activation of all muscles, except for the anterior deltoid muscles, which were expected to show similar muscle activation under both unstable and stable conditions.

Methods

Participants

Young fit male university students ($n = 30$; age: 23 ± 1.13 years; height: 178.87 ± 8.21 cm; body mass: 78.01 ± 8.5 kg; body fat percentage: $11.48 \pm 3.18\%$; and biacromial (shoulder) width: 42.22 ± 12.81 cm) voluntarily participated in this study. Participants had a minimum of 1 year of resistance training experience, performing at least two sessions/wk at moderate to vigorous intensity. No participant included in this study had musculoskeletal pain, neuromuscular disorders, or any form of joint or bone disease. The present study was performed during the spring. All participants signed an institutional informed consent form before starting the protocol, and the institutions' review board of the University of Valencia (Spain) 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.

Procedures

Each participant took part in two types of sessions: (1) familiarization and (2) experimental sessions, both at the same time in the morning. The first session occurred 48–72 hours before the 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 hours before the sessions and no physical activity more intense than daily activities 12 hours before the exercises. They were instructed to sleep >8 hours the night before data collection.

During the familiarization session, participants were familiarized with the push-up exercise, unstable devices, movement amplitude, body positioning, and the cadence of movement that would later be used during data collection. Participants practiced the exercises one to three times each. The participants' height (IP0955, Invicta Plastics Limited, Leicester, England), body mass, body fat percentage (Tanita model BF-350; Tanita Corp., Tokyo, Japan), and biacromial width were obtained according to the protocols used in previous studies.[10]

The protocol started with the preparation of the participants' skin and was followed by electrode placement, determination of the maximum voluntary isometric contraction (MVIC), and exercise performance. 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. The electrodes were positioned according to the recommendations of Cram et al[11] on the anterior deltoid (DELT), serratus anterior (SERRA), rectus femoris (FEM), and lumbar multifidus (LUMB), on the dominant side of the body.

In detail, distal and proximal pregelled bipolar silver/silver chloride surface electrodes (Blue Sensor M-00-S, Medicotest, Olstykke, Denmark) were placed with an interelectrode distance of 25 mm on the following muscle groups: (1) DELT (on the anterior aspect of the arm, ~4 cm below the clavicle, parallel to the muscle fibers); (2) SERRA (horizontally, just below the axillary area, at the level of the inferior tip of the scapula, and just medial and anterior to the latissimus dorsi; the electrodes were anterior to the latissimus dorsi muscle); (3) LUMB (parallel to the spine, ~2 cm from the L-3 vertebra over the muscle mass); and (4) FEM (on the center of the anterior surface of the thigh, approximately half the distance between the knee and the iliac spine, parallel to the muscle fibers). A reference electrode was placed 10 cm away from the midpoint of the two electrodes of each muscle, according to the manufacturer's specifications. All signals were acquired at a