MAINTENANCE OF EMG ACTIVITY AND LOSS OF FORCE OUTPUT WITH INSTABILITY

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ABSTRACT. Anderson, K.G., and D.G. Behm. Maintenance of EMG activity and loss of force output with instability. J. Strength Cond. Res. 18(3):637–640. 2004.—Swiss Balls used as a platform for training provide an unstable environment for force production. The objective of this study was to measure differences in force output and electromyographic (EMG) activity of the pectoralis major, anterior deltoid, triceps, latissimus dorsi, and rectus abdominus for isometric and dynamic contractions under stable and unstable conditions. Ten healthy male subjects performed a chest press while supported on a bench or a ball. Unstable isometric maximum force output was 59.6% less than under stable conditions. However, there were no significant differences in overall EMG activity between the stable and unstable protocols. Greater EMG activity was detected with concentric vs. eccentric or isometric contractions. The decreased balance associated with resistance training on an unstable surface may force limb musculature to play a greater role in joint stability. The diminished force output suggests that the overload stresses required for strength training necessitate the inclusion of resistance training on stable surfaces.

KEY WORDS. muscle activation, isometric, dynamic, resistance training, Swiss ball

INTRODUCTION

There has been a lack of research examining the use of unstable platforms and their effects on force and muscle activation of the upper body musculature. The use of unstable training environments has been purposed in the popular literature to enhance sport-specific training effects through increased activation of stabilizers and trunk muscles. Korneki and Zasorlich (12) revealed that, when a person becomes unstable, it necessitates muscle-stabilizing functions. The effectiveness of Swiss ball training has been demonstrated with abdominal training. Siff (16) found that the wider range of movement (with an optimal starting position from a few degrees of active trunk extension, as is the case on the Swiss ball) is preferable to similar actions performed in most circuit-training gyms. Vera-Garcia et al. (20) identified higher electromyographic (EMG) activity when performing a sit-up on an unstable surface compared with a flat surface. Conversely, Behm et al. (3) examined isometric contractions of the quadriceps and plantar flexors and reported significant decreases in force and muscle activation with the unstable platforms. They suggested that moderate but not extreme instability may allow for overload stress to be placed on the lower limb musculature. There has not been any evidence, other than anecdotal, to demonstrate the overall effectiveness of Swiss Ball training. Furthermore, there have not been any studies examining the effect of unstable platforms on upper-body muscle limb force and activation. Instability may arise not only from the base or platform but also from the implements utilized. The use of free weights with training has been advocated as more beneficial than machines, partially due to their inherent instability.

The major advantages of free weights would be derived from the ability of free-weight exercises to mimic the movement demands of real-life sport and activities of daily living (7, 14, 17, 18). This use of free weight is fundamental in the principles of exercise specificity (training in a specific manner to produce a specific outcome). Furthermore, free weights permit 3-dimensional movement and do not hinder the movement pattern (1). Thus, instability can be incurred through both stable and unstable bases (platforms) and forms of resistance. However, there have been no studies that have included free weights to investigate the effect of stability of both the platform and the resistance modality on muscle performance.

The objective of this investigation was to compare muscular activation patterns under stable and unstable conditions with both isometric and dynamic resistance movement patterns. Based on previous research, it was hypothesized that EMG activity would be greater with dynamic rather than isometric contractions (5, 8) and EMG activity would be lower during the unstable movement compared with the stable movement (3).

MATERIALS AND METHODS

Experimental Approach to the Problem

Under randomized conditions, subjects performed resistance chest press exercises under stable (bench) and unstable (Swiss ball) conditions. Resistance exercises included a maximum and 75% of maximum isometric chest press, as well as a 75% of the 1 repetition maximum (1RM) dumbbell chest press. Forces were recorded during the isometric condition. EMG activity of the pectoralis major, deltoid, triceps, latissimus dorsi, and rectus abdominus were monitored and compared to determine differences associated with stability and type of muscle contraction.

Subjects

Ten healthy male subjects with mean age, weight, height, and years of lifting experience (26.2 ± 6.0 years, 87.3 ± 12.2 kg, 177.3 ± 6 cm, and 7.9 ± 4.4 years) from Memorial University of Newfoundland participated in the study. All subjects had multiple years of resistance training experience using traditional stable platforms and devices. In addition, subjects had either included instability (Swiss balls) in their resistance training programs in the previous year or were provided with 3 orientation sessions prior to testing. The subjects were assigned to stable and unstable conditions in a balanced and randomized fashion in order to nullify any treatment order effects. All subjects were fully informed of the procedures and signed a consent form prior to experimentation. Memorial University of Newfoundland Human Investigation Committee approved the study.

Measurement and Instrumentation

Electromyography. EMG signals were measured from 5 locations; sternal origin of the pectoralis major, midbelly of the
anterior deltoid, and the long head of triceps, latissimus dorsi (lateral of scapula), and rectus abdominus (1 in. lateral of umbilicus). All surface electrodes were placed on the right side of each subject. EMG location sites were identified, shaved, sanded (to remove dead epithelial cells), and cleansed with rubbing alcohol to decrease resistance and achieve maximal adhesion of the electrode. The EMG signal was collected at 2,000 Hz, amplified ($\times$1,000), filtered (10–1,000 Hz), and smoothed (10 samples) (Biopac Systems MEC 100; Biopac Systems Inc., Holliston, MA). The maximum amplitude of the root mean square (RMS) of the EMG signal was evaluated with the Acqknowledge software program (Acqknowledge III; Biopac Systems Inc.).

**Force.** Modified handgrips were connected to a force transducer (Omega, Universal 3SB load cell; BLH Electronics) securely fastened to the floor beneath the lifting platform. Signals were amplified (MEC 100 amplifier; Biopac Systems, Canton, MA) and monitored on a computer screen (Daytek computer monitor) after being directed through an analog-digital converter (DA 100: analog-digital converter MP100WSW; Biopac Systems Inc.). All data were recorded on a Sona Phoenix computer at a sampling rate of 2,000 Hz and analyzed with Acqknowledge software program.

**Protocol**

**Platform.** The stable condition was achieved by having each subject assume a supine position on an exercise bench. Feet were flat on the floor about shoulder width apart and knees flexed to 90°. Head, shoulders, and buttocks rested on the bench, with a normal arch in the lumbar spine.

An unstable position was adopted by taking a supine position on a Thera-Band Exercise Ball (Akron, OH). Subjects stabilized their body by positioning their feet, shoulder width apart on the floor. Shoulders rested on the ball while buttocks and head were not supported. All testing was performed in a single session.

**Resistance.** For the stable and unstable isometric protocols, each subject performed a number of practice attempts to familiarize themselves with the movement. A set of modified hand grips were strapped to a bar connected to a Wheatstone bridge configuration strain gauge (Omega Engineering Inc., Don Mills, ON) securely attached to a platform on the floor. The upper arm was positioned parallel to the ground with elbows pointed directly out to the side. A 90° angle was formed at the elbow, resulting in the forearm pointing up toward the ceiling. The maximal voluntary contraction (MVC) was then established under both stable and unstable conditions (Figure 3.1). Submaximal (75% of MVC) contractions were also performed for comparison. Isometric contractions were held for 5 seconds.

For the dynamic protocol, subjects were first tested to establish their 1RM chest press with dumbbells under stable conditions. Dumbbells were held with a pronated grip, with hands slightly wider than shoulder width apart and elbows pointed out to the sides and flexed at 90°. Subjects inhaled as the weight was lowered at a slow to moderate rate of speed and exhaled during the up phase to relieve intrathoracic pressure. The eccentric portion of the contraction ceased when the arms reached the same position as used for the isometric chest press (elbows pointed out to the sides and flexed at 90°). This bottom position was held for 1 second. Subjects were controlled for speed (2 seconds down, 1 second isometric, 2 seconds up) via a digital time display at close
and unstable EMG for both the submaximal isometric and dynamic protocols. However, there was significant evidence for contraction-type effect. EMG activity during concentric contractions of the pectoralis major was 22.1% and 19.9% greater than eccentric and isometric contractions, respectively ($p = 0.006$). The deltoid exhibited 38.3% greater concentric EMG activity than eccentric ($p = 0.007$). Deltoid isometric EMG activity was not significantly different from the other two types of contractions. There were no significant differences among the different types of triceps contractions.

**DISCUSSION**

Limb muscles may be forced to aid in joint stability when performing unstable movements. With this added effort being directed to joint stability, total force output may decrease (5). The proponents of training under unstable conditions with a Swiss Ball claim that the instability provides a greater stress to the overall musculature. Stress, according to Selvey's (15) adaptation curve is essential in forcing the body to adapt to new stimuli. Periodization models by Bompia (4) emphasize the importance of altering volumes, intensities, mode, or type of exercises in order to provide novel stimuli to the neuromuscular system. Furthermore, according to the concept of training specificity (2), because not all forces are produced under stable conditions (i.e., mogul skiing, shooting a puck in hockey), then training must attempt to closely mimic the demands of that particular sport. Finally, some authors (14, 19) advance the use of free weights over machines for improved training results because the balance and control of free weights forces the individual to stress and coordinate more synergist, stabilizing, and antagonist muscle groups. It has been hypothesized that performing exercises on unstable platforms further stresses synergistic and stabilizing muscles.

In the present study, maximal isometric force output with the unstable chest press condition was significantly lower (59.6%) than in the stable condition. This finding supports Kornecki and Zschorlich (12), who identified that a percentage of force output was diverted to joint stabilization. Similarly, Behm et al. (3) identified decreases in the isometric force output of the quadriceps and plantar flexors when performed under unstable conditions. Because EMG activity was not inhibited while unstable, a muscle group may be activated to the same extent as with stable conditions with lower force outputs or less resistance. Therefore, it is possible the muscle is maintaining EMG activity levels through a combination of force production and stabilizing functions. A possible benefit of unstable resistance training would be the ability to achieve high muscle activation (via movement and stabilizing functions) with lower resultant joint torques from the reduced loads, resulting in less stress on the articular system. Furthermore, the need for greater stabilizing responsibilities of the limb musculature may mimic more closely the typical requirements of daily activities or sport. Conversely, Johnson et al. (10) found no statistical difference in the magnitude of thumb tip forces produced in a stable vs. an unstable protocol of the thumb musculature. These findings may be explained by the changes in the activation of different muscles (muscle coordination) identified in their study.

Increases in EMG activity of muscles controlling joints while unstable or perturbed have been reported by a number of authors (6, 9). Unfortunately, as forces were not measured in these studies, no correlation to force output was presented. This discrepancy might be attributed to the muscles examined. Lear and Gross (13) examined the stabilizing function of scapular stabilizers while performing push-ups on miniature trampolines. They found no significant difference.
in stabilizer EMG activity between stable and unstable cohorts; however, they acknowledged the degree of stability induced by the miniature trampolines was likely insufficient to be considered an unstable platform. In the present study, muscles that were considered to be prime movers rather than stabilizers were evaluated. Their response to instability may differ from primarily stabilizing muscles, some of which may not have been measured with this study.

Decreases in muscle activation, as estimated using the interpolated twitch technique and integrated EMG, have been reported (3) for actions under unstable conditions. While both the present study and the study by Behm et al. (3) found significant decreases in MVC force, the latter study showed a decrease in EMG activity. The experimental design may explain these findings. Behm et al. (3) had subjects perform unilateral knee extension and plantar flexion contractions while seated. As only one leg was tested, the unilateral limb forces would generate disruptive moments or torques on the stability of the body. Thus, to maintain balance, the activation and force output of the lower limb would need to be decreased. The bilateral contractions of the upper limbs in the present study would not generate similar disruptive moments, as both limbs are involved in the movement, if the resistance could be maintained directly above the torso. Indeed, greater forces and activation might even improve stability by distorting the roundness of the ball and providing a more horizontal stable platform.

Contraction type differences in EMG activity were detected, with generally greater activity during concentric than eccentric or isometric contractions. The pectoralis major (p < 0.006) and deltoid (p < 0.007) had greater EMG activity during the concentric phase of the lifts compared with the eccentric phase, which is consistent with a number of authors (5, 8, 11).

**Practical Applications**

Bilateral contractions of the upper body under unstable conditions can lead to decreases in force output with no significant change in EMG activity levels of muscle prime movers. In light of these findings, the use of Swiss balls as a resistance training modality for strength gains can be employed to allow high muscle activation levels to be developed as well as increased reliance on stabilizing functions. As this high level of muscle activation can be achieved with less resistance, this training modality may have positive implications in progressive muscle and joint rehabilitation as well as sport-specific training. Because most sports involve a combination of stabilizing and force-producing functions (running forward in tennis, baseball pitcher wind-up, moving slap shot in hockey, and many others), instability resistance training provides similar challenges to the neuromuscular system. However, in order to induce maximum or near-maximum overload forces on the limbs, a stable platform may be necessary. It is recommended that a comprehensive, sport-specific, strength training program incorporate exercises under both stable and unstable conditions.

**References**


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