ing in almost no peripheral hypertrophic changes. Furthermore, DCCROM measurements are inherently unreliable at any velocity and provide almost no essential information regarding limb RVD adaptation to a training stimulus.

The absolute RVD values exhibited in this study compare well with previous research on similar dynamometers. Measures on a Biodex system have documented RVD levels ranging between approximately 1.5 and 17° when collected using shoulder (6) and knee protocols (7, 8), while the current study identified an RVD range between approximately 1 and 14°.

When considering the velocity position graph depicted in Figure 1, as well as the previous discussions regarding DCCROM, it is apparent that RVD is the control parameter affecting LR. Load range has been previously defined as the phase when the leg-lever couple matches the predetermined machine velocity. The limiting factors for LR then are both RVD and DCCROM. Therefore, since the total ROM is equal for all participants, as defined by hard stops, and each subject ends LR at the same point, then the only means of increasing LR is through a concomitant decrease in RVD. In other words, catching the machine preset velocity (onset of LR) is purely a function of RVD.

PRACTICAL APPLICATIONS

This study was unique in that it documented phase reliability for velocity measures, finding high reliability at a fast speed and low reliability at a slow speed. Any future use of a dynamometer should consider these findings in conjunction with data gathering. The RVD and LR data from an isokinetic repetition at high speeds may be a reliable way to measure rate of velocity development. The information gathered from this study may assist in more accurately prescribing exercise programs designed to maximize human performance outcomes requiring high limb velocity on a dynamometer.

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TRUNK MUSCLE ELECTROMYOGRAPHIC ACTIVITY WITH UNSTABLE AND UNILATERAL EXERCISES

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ABSTRACT. Behm, D.G., A.M. Leonard, W.B. Young, W.A.C. Bonsey, and S.N. MacKinnon. Trunk muscle electromyographic activity with unstable and unilateral exercises. *J. Strength Cond. Res. 19(1):193–201. 2005.*—The purpose of this cross-sectional study was to evaluate the effect of unstable and unilateral resistance exercises on trunk muscle activation. Eleven subjects (6 men and 5 women) between 20 and 45 years of age participated. Six trunk exercises, as well as unilateral and bilateral shoulder and chest presses against resistance, were performed on stable (bench) and unstable (Swiss ball) bases. Electromyographic activity of the upper lumbar, lumbosacral erector spinae, and lower-abdominal muscles were monitored. Instability generated greater activation of the lower-abdominal stabilizer musculature (27.9%) with the trunk exercises and all trunk stabilizers (37.7–54.3%) with the chest press. There was no effect of instability on the shoulder press. Unilateral shoulder press produced greater activation of the back stabilizers, and unilateral chest press resulted in higher activation of all trunk stabilizers, when compared with bilateral presses. Regardless of stability, the superman exercise was the most effective trunk-stabilizer exercise for back-stabilizer activation, whereas the side bridge was the optimal exercise for lower-abdominal muscle activation. Thus, the most effective means for trunk strengthening should involve back or abdominal exercises with unstable bases. Furthermore, trunk strengthening can also occur when performing resistance exercises for the limbs, if the exercises are performed unilaterally.

KEY WORDS. stability, erector spinae, abdominal muscles, rehabilitation, strength

INTRODUCTION

The strengthening of trunk- or core-stabilizing muscles is an important consideration for activities of daily living (ADL), sports performance, and the rehabilitation of low back pain (LBP). A strong and stable trunk (core) provides a solid foundation for the torques generated by the limbs. Increased back strength is not necessarily associated with the prevention of LBP. Some studies have reported no advantage of trunk strengthening (19) or lumbar muscularity (24) in the prevention of LBP. However, increased back strength may provide some protection from LBP when greater forces are needed for the task (8). Also, the spine may become unstable because of weak trunk-stabilizer muscles (25), and a lack of back-muscle endurance is strongly associated with LBP (22). There is general agreement that exercise is beneficial in the rehabilitation of LBP (1). Because improvements in endurance and strength may contribute to recovery, the identification of exercises that best activate the trunk-stabilizing muscles would prove beneficial for ADL and rehabilitation.

Studies have attempted to identify exercises that effectively activate trunk stabilizers. Souza et al. (25) indicated that although the "Dying Bug" exercise predominantly recruited the abdominal musculature and the "Quadruped" exercise promoted greater activation of the trunk and hip extensors, the intensity of muscle activation was insufficient to provide a strengthening effect. Similarly, the abdominal musculature was not recruited to adequate levels for strengthening when performing the pelvic tilt, abdominal hollowing, and Level 1 Trunk Stability Test (28). Arokoski et al. (4) had subjects perform a variety of stabilization exercises that induced substantial activation of the back musculature but minimal activation of the abdominal musculature for most exercises. Juker et al. (14) reported that the side-bridge–support exercise proved the best for training the abdominal wall. Few reports quantify the effectiveness of exercises for the activation of trunk stabilizers. Hence, there is a need to further evaluate the effectiveness of the diverse exercises prescribed for trunk strengthening.

A commonly prescribed adaptation to trunk-strengthening exercises is the use of unstable surfaces. It has been proposed that the demands of an unstable surface will cause an increased muscle activation to complete the exercise in a controlled manner (10). However, very few studies have examined the effects of performing exercise on unstable surfaces. The use of a labile surface with curl-ups increased abdominal muscle activation compared with curl-ups performed on a stable surface (27). Arokoski et al. (4) also found greater activation with unbalanced trunk movements. Unfortunately, they did not apply instability to all their exercises. Perhaps the addition of an unstable environment to commonly prescribed trunk-strengthening exercises would ensure greater activation of back- and abdominal-stabilizing muscles. Furthermore, it may be possible to incorporate more activation of trunk stabilizers during limb-resistance exercises with the use of an unstable base.

Traditional resistance-training exercises are more often bilateral, using either a barbell or a pair of dumbbells. Conversely, many ADL and sport actions are unilateral. Unilateral exercises may be more beneficial than bilateral actions for some ADL and sports by adhering to the concept of training specificity (23), and they may also have the additional bonus of stimulating the trunk stabilizers to a greater extent. Rather than implementing an unstable base, unilateral resisted actions would provide a disruptive moment arm (torque) to the body, providing another unstable condition. No studies have investigated the effect of resisted unilateral exercises on trunk-stabilizer activation.

Thus, the primary objective of this study was to compare the electromyographic (EMG) activity of commonly prescribed trunk-strengthening and resistance exercises with stable and unstable bases. A second objective was to compare the extent of trunk-stabilizer activation between the prescribed exercises and to determine if the activation of trunk stabilizers could be increased with modifications (unilateral and bilateral) of resistance exercises.

Whereas unstable conditions can lead to decreases in externally measured force because of the increased stabilizing function of the limb muscles (2), it was hypothesized that unstable platforms would result in greater EMG activity of trunk stabilizers with both trunk-strengthening and resistance exercises. It was also hypothesized that unilateral resistance exercises (shoulder and chest press) would induce greater activation of trunk stabilizers than would bilateral presses.

METHODS

Experimental Approach to the Problem

After an orientation session on a previous day, subjects performed a variety of common trunk-strengthening exercises as well as bilateral and unilateral dumbbell-resistance exercises targeting the upper-body musculature (shoulder and chest presses). The exercises were performed on a stable (bench) or unstable (Swiss ball) platform. Electromyographic electrodes were attached over the upper lumbar, lumbosacral erector spinae, and lower-abdominal muscles. The EMG signal was used to evaluate the extent of muscle activation with stable and unstable exercises and between exercises.

Subjects

Six men and 5 women subjects (age, 24.1 ± 7.4 years; weight, 71.5 ± 15.4 kg; height, 172.3 ± 6.5 cm) from the School of Human Kinetics and Recreation and with no history of LBP participated in the study. All subjects had previous resistance-training experience (mean = 5.2 ± 6.4 years) and were presently engaged with resistance-training activities involving free weights, resistance machines, and instability devices. Both men and women were included in the study to primarily broaden the application of the findings and also distinguish if unstable strengthening exercises elicited a different response with women. Each subject was required to read and sign a consent form before participation. The Human Investigation Committee, Memorial University of Newfoundland, approved this study.

Electromyography

Bipolar surface EMG electrodes were used to measure signals from the upper lumbar, lumbosacral erector spinae, and lower-abdominal muscles groups. All electrodes were placed on the right side of the body. Skin surfaces for electrode placement were shaved, abraded, and cleansed with alcohol to improve the conductivity of the EMG signal. Electrodes (Kendall Medi-trace 100 series, Chikopee, MA) were placed 2 cm lateral to L5-S1 spinous processes for the lumbosacral erector spinae and 6 cm lateral to the L1-L2 spinous processes for the upper lumbar erector spinae muscles. Additional electrodes were placed superior to the inguinal ligament and 1 cm medial to the anterior superior iliac spine (ASIS) for the lower-abdominal stabilizers.

The EMG signals were amplified (Biopac Systems MEC 100 amplifier, Santa Barbara, CA), monitored, and directed through an analog-digital converter (Biopac MP100) to be stored on the computer (Sona, St. John's, Newfoundland, Canada). The EMG signals were collected at 2000 Hz and amplified (1,000×). By using the AcqKnowledge software program (AcqKnowledge III, Biopac System Inc., Holliston, MA), the EMG signal was rectified, filtered (10–500 Hz), and smoothed (10 samples), and the amplitude of the root mean square (RMS) EMG signal was calculated over the duration of the activity.

Electromyographic activity was normalized to back extension and abdominal-hollowing maximum voluntary contractions (MVCs). Because all exercises were performed in 1 session and the comparisons were within subject, a normalization procedure would not be necessary. However, this normalization procedure would allow a comparison of the relative activation of calisthenic-type trunk-strengthening and resistance exercises with the activation of an MVC of exercises commonly used to test or activate the trunk stabilizers (21). Normalized EMG values are described as a percentage of the EMG activity during their respective maximum-exertion normalization exercise.

Normalization Exercises

Subjects were asked to lie prone on a padded table for a maximum-exertion back-extension exercise (for normalization of the lumbosacral and upper lumbar erector spinae muscle groups). After the investigator (AML) palpated each subject's ASIS, the subject was positioned so that body segments superior to the ASIS extended off the supporting table. The subject's lower body was then secured to the table with 3 straps located just superior to the ankles, knees, and gluteal folds. A strap that encircled the subject's trunk, positioned at the T5 or T6 level, maintained the upper body parallel to the floor. The strap was attached with a high-tension wire to a metal plate secured to the floor.

When performing the abdominal-hollowing exercise (for the lower-abdominal stabilizers), the subjects lay on a mat on the floor with their knees bent and feet flat on the floor. They attempted to pull their abdominal muscles in and up, toward their spine and diaphragm, as intensely as possible, forming a "J" shape. They held the contraction for 3 seconds.

Exercise Procedure

All subjects attended an orientation (practice) session at least 24 hours before testing to familiarize themselves with the exercises.

The exercises were performed with a random allocation technique on both a bench and a Swiss ball (TheraBand Inc., Akron, OH). A bench 50 cm high was matched with a Swiss ball with a maximum diameter of 55 cm. The diameter of the Swiss ball, however, was depressed to approximately 50 cm with the addition of the subject's mass. The subjects were positioned on the Swiss ball to ensure that the orientation of the trunk and angle of hips and knees were similar to their positioning on the bench. Trunk exercises were held for 3 seconds each. The contractions were sufficient to maintain proper form while performing the exercise. All exercises were performed during a single experimental session with a 2-minute rest between each exercise. Each exercise was performed twice, and the mean amplitude of the RMS EMG was taken for each muscle. Exercises included both stable and unstable versions of the activities listed below.

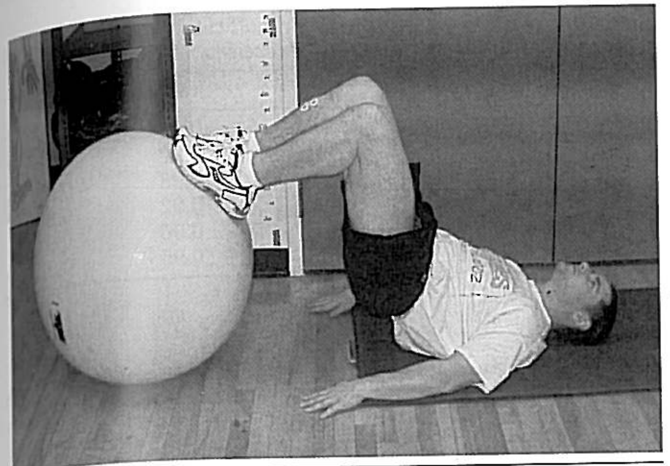

FIGURE 1. Bridge.

Bridge. Subjects lay supine on the floor with knees bent at 90° and legs placed on the support. Hips were raised until the torso was 45° to the floor (Figure 1).

Pelvic Tilt. While seated with feet flat on the floor, subjects consecutively contracted hip flexors and extensors to rotate their hips in a posterior and anterior direction. Arms were folded in front of the body (Figure 2).

Alternate Arm and Leg Extension. Initially, a 4-point stance was assumed on the hands and knees with hands directly under the shoulders and thighs perpendicular to the floor. The contralateral arm and leg were extended until both were parallel to the floor. The same action was repeated for the opposite limbs. Throughout the study, an alternate arm and leg extension right will refer to having the right arm and left leg extended, and an alternate arm and leg extension left will refer to a left arm and right leg extended. With the Swiss ball, subjects performed the same action with their stomach supported by the ball and toes and fingertips touching the ground (Figure 3).

Parallel Hold. Subjects lay prone with their feet either on the floor or on the ball and with their hands under their shoulders. They pushed up, straightening their arms (Figure 4).

Side Bridge. Subjects lay on their side with their legs straight and elevated on the platform. They elevated their hips until their torso was 45° to the floor (Figure 5). The exercise was performed on both the right and left sides. Side bridge right refers to a position where the subjects supported their body on their right limbs and elevated their left hip. Side bridge left refers to a position where the subjects supported their body on their left limbs and elevated their right hip.

Superman. Subjects lay prone on the support with shoulders, arms, hips, and legs extended. Feet were shoulder-width apart and flat against a wall for support (Figure 6).

Chest Press. Subjects lay supine on the support with feet on the floor and knees flexed at 90°. Bilateral contractions started with upper arms parallel to the floor and elbows at 90°. Dumbbells were then pushed to a fully extended position. Unilateral contractions were similar, except the non–weight-supporting arm was maintained at the waist. Both arms were tested unilaterally.

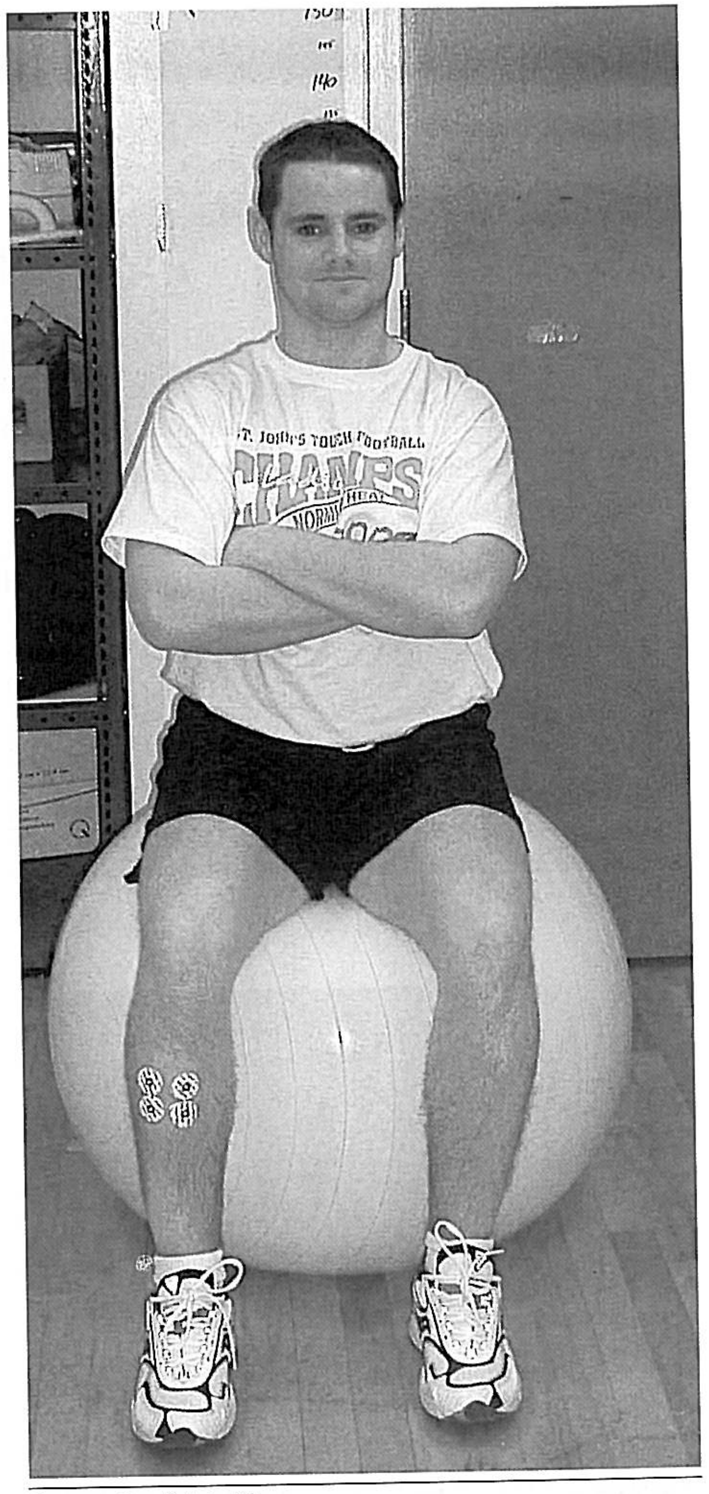

FIGURE 2. Pelvic tilt.

Shoulder Press. While seated with upper arms parallel to the floor and elbows at 90°, subjects fully extended the dumbbells either bilaterally or unilaterally. The non–weight-supporting arm was maintained at the waist for unilateral contractions. Both arms were tested unilaterally.

Male subjects performed both resistance exercises with 13.6-kg (30-lb) dumbbells, whereas female subjects used 6.8-kg (15-lb) dumbbells. The tempo of the presses was dictated by a metronome resulting in a 1-second con-

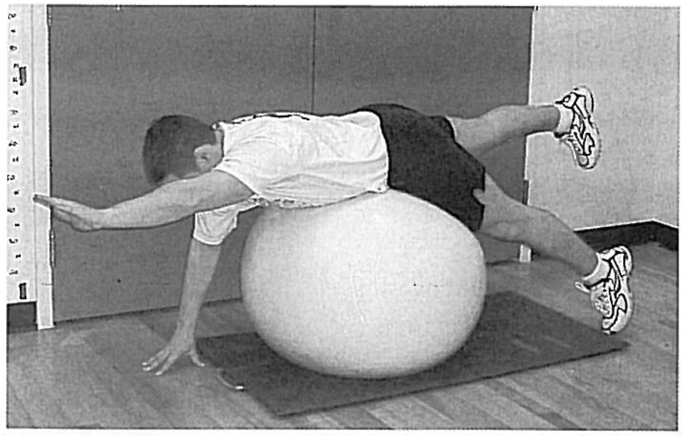

FIGURE 3. Alternate arm and leg extension.

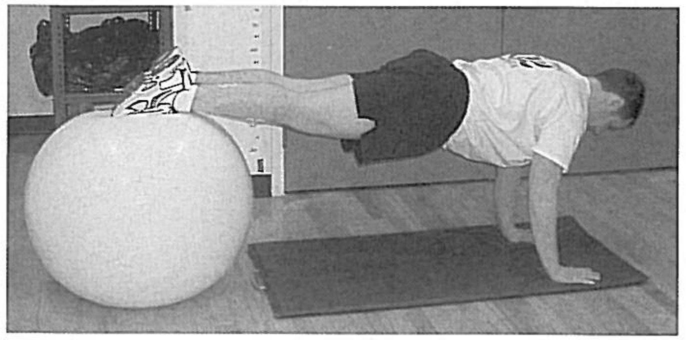

FIGURE 4. Parallel hold.

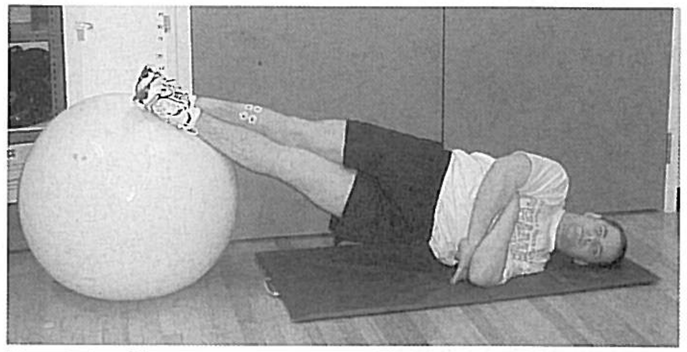

FIGURE 5. Side bridge.

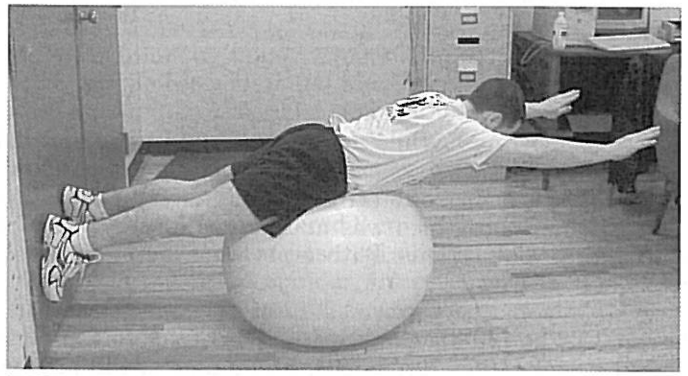

FIGURE 6. Superman.

TABLE 1. Intraclass correlation coefficients for the test-retest electromyographic activity of all exercises.

Exercise	Stable	Unstable
Bridge	0.95	0.81
Pelvic tilt	0.92	0.82
Alternate arm and leg extension	0.98	0.97
Parallel hold	0.92	0.80
Side raise	0.96	0.97
Superman	0.95	0.90

centric, 1-second isometric contraction at full extension, and a 1-second eccentric action.

Statistical Analyses

For each muscle group, data were analyzed with separate 3-way analyses of variance (ANOVAs) with repeated measures on 2 levels. The 3 levels for 1 set of ANOVAs were gender, stability, and calisthenic trunk-strengthening exercises (2 × 2 × 8). The levels for the other ANOVAs were gender, stability, and chest press dumbbell-resistance exercises (2 × 2 × 3) as well as gender, stability, and shoulder press dumbbell-resistance exercise (2 × 2 × 3). Trunk-strengthening exercises were analyzed separately from the resistance exercises because the major purpose of the calisthenic exercises was to activate the trunk stabilizers, whereas trunk stabilization is a secondary function of the dumbbell-resistance presses. Because the dumbbell-press exercises were performed either supine (chest press) or seated (shoulder press), it was decided to analyze the press exercises separately as well. Where significant differences were detected ($p \le 0.05$), a Bonferroni (Dunn) procedure was used to identify the individual differences among the exercises. Effect sizes (ES) are reported in parentheses within the results. Reliability was assessed with a Cronbach α model intraclass correlation coefficient (ICC) (18) with all subjects. Repeated tests were conducted within a single testing session. The means and *SEM* are illustrated in Figures 7–12.

RESULTS

The important findings of this study include the overall increase in lower-abdominal muscle activation (EMG) levels resulting from the unstable calisthenic exercises, with little to no evidence of greater activation with the resistance exercises. Furthermore, all trunk stabilizers were activated to a greater extent with unstable chest presses. In addition, greater trunk-stabilizer muscle activation was found with unilateral dumbbell presses (shoulder and chest) of the contralateral arm than with the ipsilateral arm or bilateral presses. No significant gender effects were established with this study. The test-retest reliability of the measures with ICCs could all be classified as excellent (Table 1).

In the following sections, the figures illustrate the relative EMG activity of the trunk-strengthening exercises in relation to the normalized or reference activity (EMG ratio). In the text, percentage values associated with individual exercises in parentheses represent the percentage EMG activity in reference to the exercise with the greatest activity (e.g., the bridge exercise produced 48.7% of the superman upper lumbar erector spinae EMG activity).

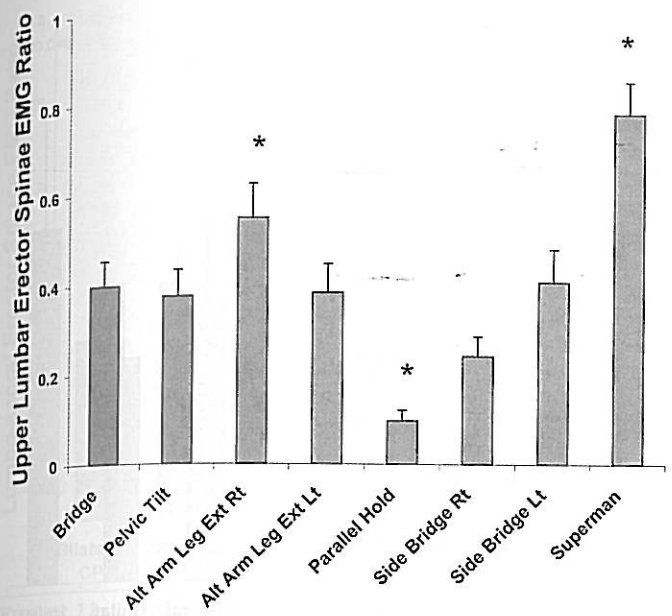

FIGURE 7. The graph depicts the mean electromyographic (EMG) activity of the upper lumbar erector spinae muscles during the performance of trunk exercises. Bars depict the mean combined data of the individual stable and unstable exercises (data collapsed over stability). The EMG activity was compared with a stable and supported maximal voluntary isometric contraction (MVC) back extension. A ratio was calculated between the trunk exercises and the reference activity (MVC back extension). Asterisks indicate that the exercise was significantly different from all other exercises. Vertical bars represent *SEM*.

Trunk-Strengthening Exercises

Upper Lumbar Erector Spinae. No significant *p* values were for stability on the upper lumbar erector spinae (ES = 0.77). However, with data collapsed over gender and stability, significant differences ($p < 0.001$) were between the individual exercises (Figure 7). The superman exercise induced significantly greater activation than did the bridge (51.3% of superman; ES = 1.32), pelvic tilt (48.0%; ES = 1.55), alternate arm and leg extension left (49.1%; ES = 1.44), parallel hold (12.3%; ES = 2.95), side bridge right (30.8%; ES = 0.82), and side bridge left (51.9%; ES = 0.62).

Lumbosacral Erector Spinae. There was a trend ($p = 0.08$) for unstable exercises to procure greater activation (4.7%) than the stable exercises did for the lumbosacral erector spinae (data collapsed over gender and exercises). With the data collapsed over gender and stability, a significant difference ($p < 0.0001$) was in the activation levels of the individual exercises (Figure 8). The superman exercise provided significantly greater lumbosacral erector spinae activation than did the bridge (84.6% of the superman, ES = 0.5), pelvic tilt (50.3%, ES = 2.13), alternate arm and leg extension right (65.6%, ES = 1.5), alternate arm and leg extension left (62.7%, ES = 1.33), parallel hold (12.5%, ES = 3.18), side bridge right (34.5%, ES = 3.18), and side bridge left (61.0%, ES = 1.38).

Lower-Abdominal Stabilizers. The unstable exercises resulted in significantly ($p = 0.007$) greater activation (27.9%) than did the stable exercises (data collapsed over gender and exercises). With the data collapsed over gen-

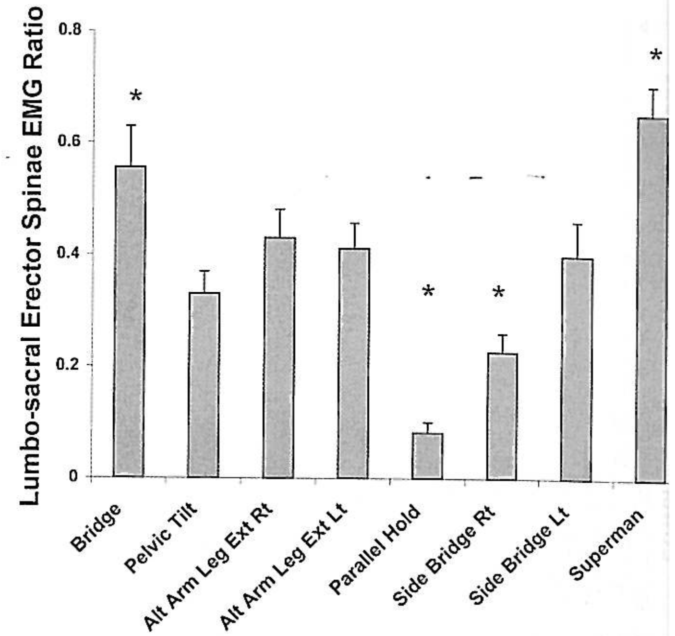

FIGURE 8. The graph depicts the mean electromyographic (EMG) activity of the lumbosacral erector spinae muscles during the performance of trunk exercises. Bars depict the mean combined data of the individual stable and unstable exercises (data collapsed over stability). The EMG activity was compared with a stable and supported maximal voluntary isometric contraction (MVC) back extension. A ratio was calculated between the trunk exercises and the reference activity (MVC back extension). Asterisks indicate that the exercise was signi icantly different from all other exercises. Vertical bars represent *SEM*.

der and stability, a significant difference ($p = 0.002$) wa between the activation levels of the individual exercise (Figure 9). The side bridge left showed greater activatio of the right lower-abdominal stabilizers than did th bridge (30.6% of side bridge left; ES = 0.74), pelvic ti (33.8%; ES = 0.79), alternate arm and leg extension righ (46.5%; ES = 0.5), alternate arm and leg extension le (25%; ES = 0.87), parallel hold (37.3%; ES = 0.58), sid bridge right (48.2%; ES = 0.62), and superman (13.9 ES = 0.92).

Shoulder Press

Upper Lumbar Erector Spinae. No significant effects c stability were on the upper lumbar erector spinae. How ever, with the data collapsed over gender and stability, trend for differences ($p = 0.09$) was between the individ ual exercises (Figure 10). The left arm unilateral shoulde press brought about the greatest activation of the righ upper lumbar erector spinae. The bilateral and right arn unilateral shoulder press exhibited 91.1% and 66.6% c the left arm unilateral shoulder press EMG activity.

Lumbosacral Erector Spinae. No significant effects o stability were on the lumbosacral erector spinae. How ever, with the data collapsed over gender and stability, significant difference ($p < 0.001$) was between the indi vidual exercises (Figure 11). The left arm unilatera shoulder press showed the greatest activation of the righ lumbosacral erector spinae. The bilateral and right arn unilateral shoulder press exhibited 86.3% (ES = 0.74

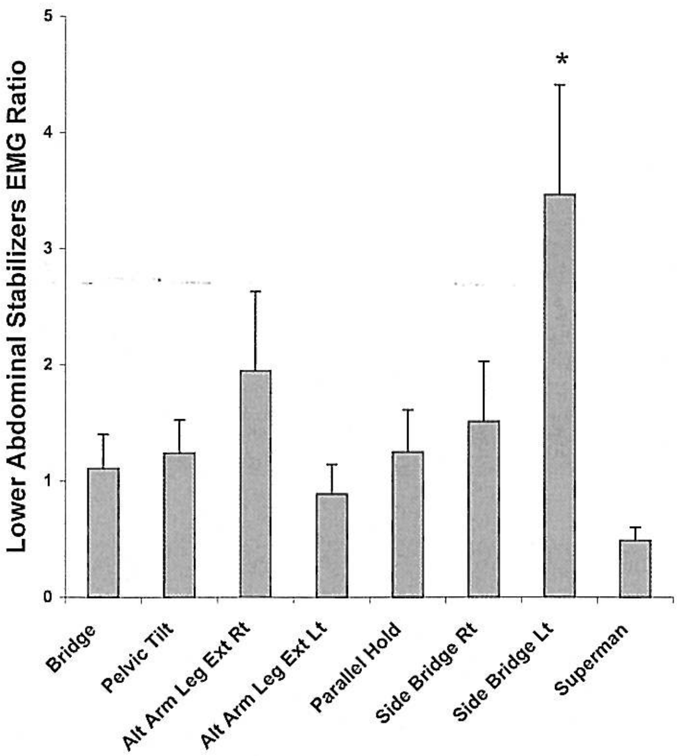

Figure 9. The graph depicts the mean electromyographic (EMG) activity of the lower-abdominal stabilizing muscles during the performance of trunk-strengthening exercises. Bars depict the mean combined data of the individual stable and unstable exercises (data collapsed over stability). The EMG activity was compared with a stable maximal voluntary isometric contraction (MVC) abdominal-hollowing activity. A ratio was calculated between the trunk exercises and the reference activity (abdominal-hollowing MVC). Asterisks indicate that the exercise was significantly different from all other exercises. Vertical bars represent *SEM.*

and 33.3% (ES = 1.81) of the left arm unilateral shoulder press EMG activity.

Lower-Abdominal Stabilizers. No significant differences were in activation across stability or individual exercises (Figure 12).

Chest Press

Upper Lumbar Erector Spinae. The unstable exercises caused a significantly ($p = 0.0005$, ES = 2.51) greater activation (37.7%) than did the stable exercises (data collapsed over gender and exercises). With the data collapsed across gender and stability, the left arm unilateral chest press caused significantly ($p = 0.007$) greater activation of the right upper lumbar erector spinae than did the right arm unilateral (63.2% of the left arm unilateral chest press, ES = 0.89) and bilateral chest press (71.7%, ES = 1.02) (Figure 10).

Lumbosacral Erector Spinae. The unstable exercises produced a significantly ($p < 0.03$, ES = 1.46) greater activation (54.3%) than did the stable exercises (data collapsed over gender and exercises). With the data collapsed across gender and stability, a trend ($p = 0.09$) was found for differences between the individual exercises (Figure 11). The bilateral and right arm unilateral chest press exhibited 50% and 66.6% of the left arm unilateral chest press EMG activity.

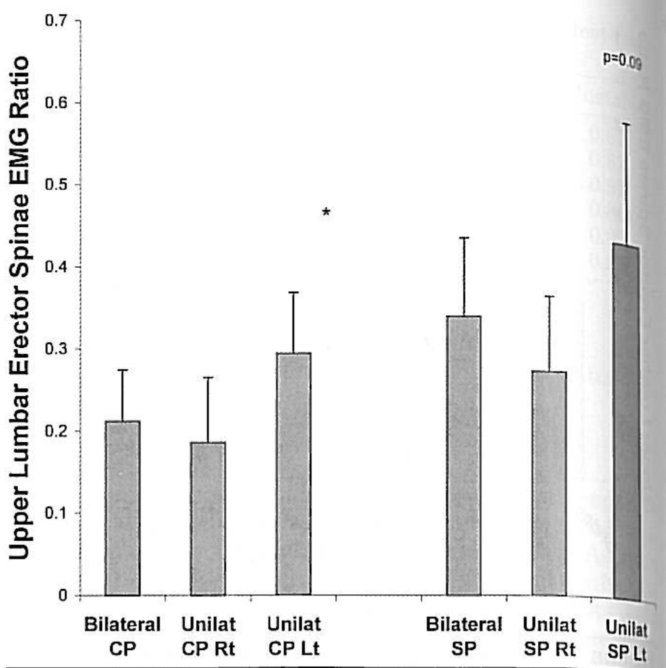

Figure 10. The graph depicts the mean electromyographic (EMG) activity of the upper lumbar erector spinae muscles during the performance of bilateral and unilateral (Unilat) chest (CP) and shoulder press (SP) exercises. Bars depict the mean combined data of the individual stable and unstable exercises (data collapsed over stability). The EMG activity was compared with a stable and supported maximal voluntary isometric contraction (MVC) back extension. A ratio was calculated between the chest and shoulder press exercises and the reference activity (MVC back extension). Asterisks indicate that the exercise was significantly different from the other 2 press conditions (bilateral and right unilateral). The EMG activity was not compared between the 2 types of presses. Vertical bars represent *SEM.*

Lower-Abdominal Stabilizers. A trend ($p = 0.1$) was found for a stability effect on the lower-abdominal stabilizers (data collapsed over gender and exercises). The unstable exercises produced 37.8% greater activation than did the stable exercises. With data collapsed across gender and stability, a significant difference was between the activation levels of the individual exercises (Figure 12). The bilateral and right arm unilateral chest press exhibited 24% (ES = 2.10) and 33.2% (ES = 1.63) of the left arm unilateral chest press EMG activity ($p < 0.01$).

DISCUSSION

Instability with trunk-strengthening exercises increased the activation of the lower-abdominal muscles. Although no effect of instability was on the shoulder press, the chest press had either significantly greater or tendencies toward greater activation of the upper lumbar erector spinae, lumbosacral erector spinae, and lower-abdominal muscles. Moreover, unilateral dumbbell presses of the contralateral arm exhibited greater activation of the lumbosacral and upper lumbar erector spinae with both shoulder and chest presses. However, lower-abdominal muscle activation was significantly greater only with the unilateral dumbbell press of the contralateral arm with the chest press.

General descriptive (e.g., lumbosacral and upper lumbar erector spinae) rather than specific (e.g., multifidus, longissimus) trunk-muscle terminology was used in this study according to the conflicting findings of similar studies. A number of studies have used a similar L5-S1 electrode placement to measure the EMG activity of the multifidus (9, 11, 12, 20). In contrast, Stokes et al. (26) reported that accurate measurement of the multifidus requires intramuscular electrodes. Thus, the EMG detected by these electrodes in the present study is referred to as lumbosacral erector spinae muscle activity. According to anatomic nomenclature, erector spinae muscles include both superficial (e.g., spinalis, longissimus, iliocostalis) and deep (e.g., multifidus) vertebral muscles (13, 16). Back muscles have also been described as local and global stabilizing muscles on the basis of their role in stabilizing the trunk (6). The multifidus is described as a component of the local stabilizing system, whereas the longissimus contributes to the global stabilizing system. The upper lumbar erector spinae EMG electrode positioning was more lateral than was the lower-back EMG positioning in order to diminish the detection of multifidus activity and thus emphasize the measurement of global stabilizing muscles (longissimus). The lumbosacral erector spinae electrode positioning would represent more of the local stabilizing functions. Additional electrodes were placed superior to the inguinal ligament and medial to the ASIS for the lower-abdominal stabilizers. McGill et al. (17) reported that surface electrodes adequately represent the EMG amplitude of the deep abdominal muscles within a 15% RMS difference. However, Ng et al. (20) indicated that electrodes placed medial to the ASIS would receive competing signals from the external obliques and transverse abdominus with the internal obliques. On the basis of these findings, the EMG signals obtained from this abdominal location are described in the present study as the lower-abdominal stabilizers, which would be assumed to include EMG information from both the transverse abdominus and the internal obliques. The transverse abdominus and internal obliques are also considered to contribute to the local stabilizing system (6).

Although the classical result of increased EMG activity is an increase in externally measurable force (7, 15), muscles used to stabilize joints can significantly contribute to the EMG signal without augmenting measurable force. Increased trunk-stabilizer activation with an unstable base concurs with Arokoski et al. (4) and Vera-Garcia et al. (27). Unfortunately, Arokoski et al. (4) applied an unstable base to only 2 of the 15 exercises they used. In addition, the majority of the activities they chose created greater stress on back musculature rather than abdominal musculature. Vera-Garcia et al. (27) examined only curl-ups and found increased abdominal muscle activity with labile surfaces. To our knowledge, no other published studies have examined the effect of instability on a wide variety of trunk-stabilization exercises. Anderson and Behm (3) had subjects perform squats under differing degrees of stability. Similar to the present study, higher degrees of instability resulted in greater activation

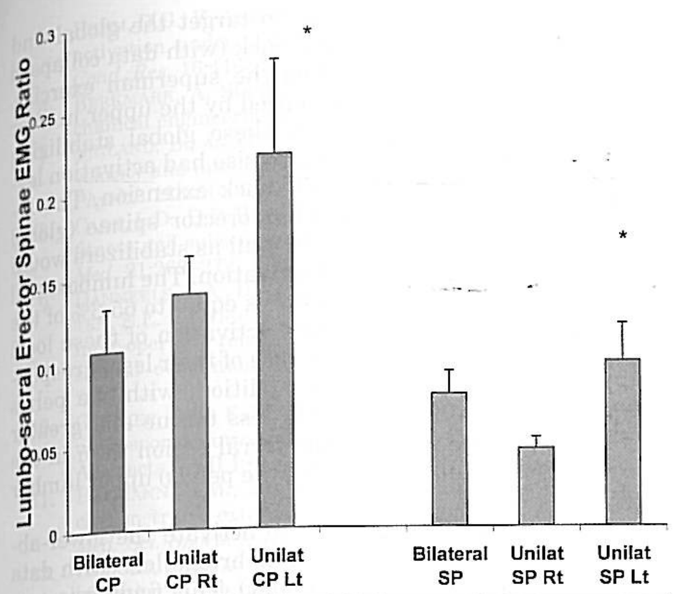

Figure 11. The graph depicts the mean electromyographic (EMG) activity of the lumbosacral erector spinae muscles during the performance of bilateral and unilateral (Unilat) chest (CP) and shoulder press (SP) exercises. Bars depict the mean combined data of the individual stable and unstable exercises (data collapsed over stability). The EMG activity was compared with a stable and supported maximal voluntary isometric contraction (MVC) back extension. A ratio was calculated between the chest and shoulder press exercises and the reference activity (MVC back extension). Asterisks indicate that the exercise was significantly different from the other 2 press conditions (bilateral and right unilateral). The EMG activity was not compared between the 2 types of presses. Vertical bars represent *SEM.*

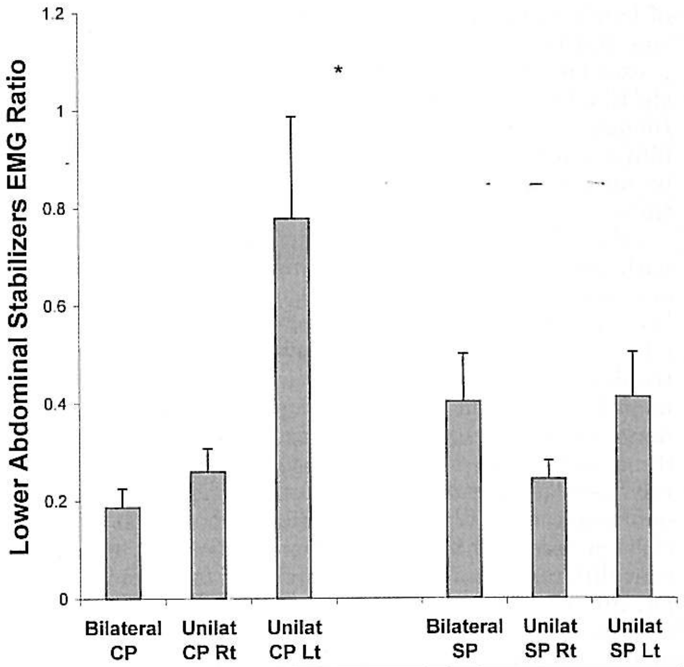

Figure 12. The graph depicts the mean electromyographic (EMG) activity of the lower-abdominal stabilizer muscles during the performance of bilateral and unilateral (Unilat) chest (CP) and shoulder press (SP) exercises. Bars depict the mean combined data of the individual stable and unstable exercises (data collapsed over stability). The EMG was compared with a stable maximal voluntary isometric contraction (MVC) abdominal-hollowing activity. A ratio was calculated between the trunk exercises and the reference activity (abdominal-hollowing MVC). Asterisks indicate that the exercise was significantly different from the other 2 press conditions (bilateral and right unilateral). The EMG activity was not compared between the 2 types of presses. Vertical bars represent *SEM.*

of trunk-stabilizing muscles. In another study by Anderson and Behm (2), isometric chest-press forces were depressed by 60% under unstable conditions, although muscle EMG activity was not significantly altered. Thus, although externally measured forces are impaired by instability, muscle activation can be maintained or increased because of the increased reliance on stabilization functions.

Not all studies have found increased muscle activation with more unstable bases. Behm et al. (5) found a decrease in force output and EMG activity when performing leg extensions and plantar flexor contractions while seated on an unstable surface. However, limb rather than trunk-stabilizer muscles were examined. Although the unstable platform may have made it difficult to exert maximal force and therefore result in less prime mover (limb) activation, trunk muscles could have actually had increased activity. Unfortunately, trunk musculature was not monitored. When comparing stable with unstable chest presses, Anderson and Behm (2) found no significant difference in the EMG activity of the pectoralis major, anterior deltoid, triceps, latisimus dorsi, and rectus abdominus. Once again, the instability-induced decrement in prime mover or limb force and activation may not parallel possible increases in trunk-stabilizer activity. Although Anderson and Behm (2) did measure a trunk muscle, the primary responsibilities of the rectus abdominus are trunk flexion and rib depression (16) rather than stabilization. Thus, although an unstable base may decrease the potential for external force output and therefore result in impaired limb muscle activation (2, 5), the trunk stabilizers must compensate for the instability by increasing their activity.

Instability-induced increases in trunk-muscle activation were also found with the unstable chest-press resistance exercise but not the shoulder press. Although a Swiss ball was incorporated into the unstable shoulder press, instability may not have been achieved because of the positioning of the center of gravity. The subject's center of gravity while seated would be positioned directly over the center of gravity of the ball, hence creating a somewhat stable base. In fact, Swiss balls are often advocated to promote proper posture while seated in order to prevent LBP (21). In contrast, the subject's center of gravity during a chest press would be outside the base of Swiss ball support, thereby necessitating more stabilizing activity. Trunk-stabilizer activation during a chest press with an unstable base exceeded activation with a stable base by 37–54%.

Instability is induced not only through the use of unstable bases such as a Swiss ball, but also with destabilizing torques. Unilateral dumbbell presses of the contralateral arm exhibited greater activation of the lumbosacral and upper lumbar erector spinae with both shoulder and chest presses. The unbalanced movement of a resistance by a single arm outside the base of support (center of gravity) would lead to a destabilizing torque that must be countered by contractions of the contralateral trunk musculature. It is common for many individuals to train with 2 dumbbells, moving them consecutively. However, the mass of the contralateral dumbbell would provide a counterbalance, diminishing the destabilizing moment arm of the unilateral movements. To more highly activate the trunk stabilizers while training the upper limbs, only 1 dumbbell should be handled during the action.

The most efficient exercise to target the global and local stabilizing muscles of the back (with data collapsed over stability and gender) was the superman exercise. The greatest effect was experienced by the upper lumbar erector spinae. The activity of these global stabilizing muscles during the superman exercise had activation levels equal to 77.3% of the MVC back extension. The responsibility of the upper lumbar erector spinae (global stabilizers) as back extensors as well as stabilizers would contribute to this substantial activation. The lumbosacral erector spinae had activation levels equal to 65.6% of the MVC back extension. The lower activation of these local stabilizing muscles may be because of their lesser responsibility as back extensors. In addition, with the pelvis supported by the bench or ball, less torque and greater stability would be in the lumbosacral region than in the more superior or distal (distal to the pelvis) upper lumbar region.

The most efficient exercise to activate the lower-abdominal musculature was the side bridge left (with data collapsed over stability and gender). This finding is consistent with Juker et al. (14), who found maximal abdominal activation with their side bridge support exercise.

PRACTICAL APPLICATIONS

Overall, the trunk-stabilizer muscles are more highly activated by unstable rather than stable exercises. In addition, resistance exercises with a single arm (unilateral) will also cause greater activation of the contralateral-side trunk stabilizers. In the present study, independent of the state of stability, the superman and side bridge left exercises provided the greatest activation of the erector spinae and lower-abdominal musculature respectively. Therefore, it is recommended that for strengthening or increasing the endurance of the trunk stabilizers for ADL, sports performance, or rehabilitation, the exercise should involve a destabilizing component. The lack of stability may originate from the base or platform from which the exercise is performed upon (e.g., Swiss ball, wobble board) or by placing body segments or resistance outside the base of support of the body (e.g., unilateral dumbbell-resisted movements). However, it must be recognized that when attempting to exert forces under unstable conditions, the maximum forces achieved under stable conditions are not possible because of the greater muscle-stabilization functions. Furthermore, the number of repetition maximums would also need to be adjusted to compensate for the unstable platform.

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