An Electromyographic Analysis of the Ab-Slide Exercise, Abdominal Crunch, Supine Double Leg Thrust, and Side Bridge in Healthy Young Adults: Implications for Rehabilitation Professionals

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Abstract

Youdas, JW, Guck, BR, Hebrink, RC, Rugotzke, JD, Madson, TJ, and Hollman, JH. An electromyographic analysis of the Ab-Slide exercise, abdominal crunch, supine double leg thrust, and side bridge in healthy young adults: implications for rehabilitation professionals. *J Strength Cond Res* 22(6): 1939–1946, 2008—The purpose of this study was to examine the effectiveness of a commercial abdominal machine (Ab-Slide) and three common abdominal strengthening exercises (abdominal crunch, supine double leg thrust, and side bridge) on activating abdominal and minimizing extraneous (nonabdominal) musculature—namely, the rectus femoris muscle. We recruited 10 males and 12 females whose mean (± *SD*) percent body fat was 10.7 ± 4 and 20.7% ± 3.2%, respectively. Electromyographic (EMG) data were recorded using surface electrodes for the rectus abdominis, external oblique, internal oblique, and rectus femoris. We recorded peak EMG activity for each muscle during each of the four exercises and normalized the EMG values by maximum muscle contractions (% MVIC). A two-factor repeated-measures analysis of variance assessed differences in normalized EMG activity among the different exercise variations ($p < 0.05$). Post hoc analyses were performed using the Bonferroni-adjusted α to assess between-exercise pair comparisons ($p < 0.002$). Gender did not affect performance; hence, data were collapsed across gender. We found a muscle × exercise interaction ($F_{9,189} = 5.2$, $p < 0.001$). Post hoc analyses revealed six pairwise differences. The Ab-Slide elicited the greatest EMG activity for the abdominal muscles and the least for the rectus femoris. The supine double leg thrust could be a problem for patients with low-back pathology due to high rectus femoris muscle activity.

Key Words EMG, lumbar spine, rectus abdominis, sit-up

Introduction

Abdominal muscle exercises are frequently recommended for various reasons, including enhancement of sports performance, rehabilitation of low-back pain, and to improve core strength and endurance during the performance of functional activities. Abdominal muscle exercises are a staple of many exercise programs intended to meet those goals (5). These exercises should ideally challenge the abdominal muscles (rectus abdominis [RA], internal oblique [IO], external oblique [EO], and transversus abdominis [TA]) while minimizing the input of extraneous musculature–namely, rectus femoris (RF).

Understanding the magnitude of abdominal muscle activation during different exercises is useful for practitioners seeking to prescribe the most appropriate exercise for their patients or clients. In the field of sports performance, maximal activation of the musculature is often a goal, whereas in the rehabilitation field a gentler submaximal activation may be more beneficial because of lower-spinal compressive forces (2).

Numerous traditional and commercial abdominal exercise routines have been previously described with varying primary objectives (1,2,5,6,8–10,15–18). Investigators have provided electromyographic (EMG) data from the abdominal musculature during the performance of the standard crunch, various sit-up maneuvers, bridge, and double straight leg lowering (1,2,5,6,8–10,15–18). Investigators have compared abdominal muscle EMG activity while healthy subjects performed trunk muscle exercises using a variety of commercial devices including the Ab-Doer Pro, Ab-Flex, Ab Rocker, Ab Roller, Ab Roller Plus, ABSculptor, Ab-Slide, Ab Trainer, Ab Twister, AbWorks, Super Abdominal Machine, Torso Track,

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Torso Track 2, and Perfect Abs (5,6–10,15–18). Fewer reports, however, have examined abdominal muscle EMG activity during the side bridge, and none to our knowledge have examined abdominal muscle EMG activity during the supine double leg thrust exercise (2,4,10).

Escamilla et al. (9) studied the normalized abdominal and extraneous muscle EMG activity during the performance of the Ab-Slide and crunch. Overall, the Ab-Slide yielded the highest activation of the RA, EO, and IO muscles while minimizing the activity of the RF. According to Escamilla et al. (9) the crunch produced the fourth-highest normalized mean EMG activity for the RA out of the seven exercises tested and even lower RF activation than seen during the Ab-Slide. Juker et al. (10) examined the side bridge and found moderate activation of the abdominal obliques with minimal normalized mean EMG activity of the RF. Shields and Heiss (15) examined the double leg lowering maneuver, which is similar to the supine double leg thrust, and found greater than 100% normalized EMG for the EO with high activation of the RA. However, the authors did not examine extraneous musculature.

The primary purpose of this study was to test the effectiveness of a popular commercial abdominal machine, the Ab-Slide, and three common abdominal strengthening exercises–crunch, supine double leg thrust, and side bridge–on activating abdominal and extraneous musculature–namely, the RF muscle. We selected these exercises because no previous studies have described the EMG activity for this combination of abdominal exercises. Moreover, no one has described the EMG activity of the abdominals and hip flexors during the performance of the supine double leg thrust. We hypothesized that EMG activation would be maximized in the RA, EO, and IO muscles and would be minimized in the RF muscle during the Ab-Slide exercise as compared with the abdominal crunch, supine double leg thrust, and side bridge exercises.

Methods

Experimental Approach to the Problem

In this study, we examined the EMG activity of the RA, EO, IO, and RF muscles during the performance of a commercial (Ab-Slide) and three common abdominal exercises (crunch, supine double leg thrust, and side bridge). The EMG signals were collected with surface electrodes, processed with the root mean square algorithm, and normalized to a maximum voluntary isometric contraction (MVIC). We used a repeated-measures design that used ratio data to determine the EMG activity during the four exercises. The independent variables included the four abdominal exercises (Ab-Slide, crunch, supine double leg thrust, and side bridge) and the four muscle groups (RA, EO, IO, and RF). The dependent variable was the normalized peak EMG activity of the RA, EO, IO, and RF muscles. Specifically, the study design attempted to answer the following research question: is the Ab-Slide more effective than the crunch, supine double leg thrust, or side bridge for activating the RA, EO, and IO muscles while minimizing activity of the RF muscle?

Subjects

Twenty-two healthy subjects (10 men and 12 women) with normal or lower levels of body fat (3) volunteered to participate in this study. The subjects comprised a sample of convenience and were recruited from a graduate program in physical therapy. Percent body fat (3) was calculated using data obtained from skinfold measurements and the appropriate regression equations and was then referenced to the standards set by the American College of Sports Medicine (ACSM). Mean ($\pm$ *SD*) age, body mass, height, percent body fat, and body mass index (BMI) were 25.2 $\pm$ 2.4 years, 81.8 $\pm$ 9.7 kg, 1.8 $\pm$ 0.1 m, 10.7 $\pm$ 4.0%, and 25.6 $\pm$ 3.0 $kg{\cdot}m^{-2}$, respectively, for men, and 23.3 $\pm$ 0.7 years, 63.9 $\pm$ 6.8 kg, 1.7 $\pm$ 0.1 meters, 20.7 $\pm$ 3.2%, and 22.5 $\pm$ 2.1 $kg{\cdot}m^{-2}$, respectively, for women. All subjects were informed of the potential risks and benefits of the study, and all subjects signed a written consent form in accordance with the institutional review board at the Mayo Clinic, Rochester, Minn. Individuals were excluded from participation in the study if they answered positive for one or more of the following: history of abdominal or low-back pain within 6 weeks before the study, inability to correctly perform all exercises in a pain-free manner, or if their percent body fat was higher than the standards set by the ACSM (3). Excess body fat can impair physical performance of most activities including abdominal strengthening exercise. Therefore, we recruited young, healthy subjects with low percent body fat. At the time of the study, all the subjects had been on a regular physical conditioning program that consisted of aerobic exercise and strength training for the extremities using free weights and exercise machines. All subjects self-reported that they routinely performed abdominal muscle strengthening exercises that included trunk curl-ups on both a floor and an exercise ball. Lohman et al. (11) have proposed a set of body fat standards for healthy men and women. Percent body fat standards for athletic men and women were 5–13 and 12–22%, respectively. Both our men (mean $\pm$ *SD*, 10.7 $\pm$ 4%) and women (mean $\pm$ *SD*, 20.7 $\pm$ 3.2%) would be classified as athletic according to these standards.

Materials

Before the exercise testing, skinfold measurements were obtained using a Lafayette Caliper (Lafayette Instrument Co., Lafayette, Ind). Raw EMG signals were collected with D-100 bipolar surface electrodes (Therapeutics Unlimited, Inc., Iowa City, Iowa). The active Ag-AgC1 electrodes had an interelectrode distance of 22 mm and were encased within preamplifier assemblies measuring 35 $\times$ 17 $\times$ 10 mm. The preamplifiers had a gain of 35. Conductive gel (Signa Cream Electrode Cream; Parker Laboratories, Inc., Fairfield, NJ) was used to conduct the electrical signal from the skin to the electrodes. Electrode leads from the preamplifiers were connected to a main amplifier system GCS67 (Therapeutics

Unlimited, Inc., Iowa City, Iowa). The combined preamplifier and main amplifier permitted a gain of 100–10,000 with a bandwidth of 40 Hz to 6 KHz. The common mode rejection ratio was 87 dB at 60 Hz, and input impedance was greater than 15 MΩ at 100 Hz. Data were collected at a sampling frequency of 1000 Hz. Raw EMG signals were processed with WinDaq data-acquisition software (DATAQ Instruments, Inc., Akron, Ohio). The primary piece of exercise equipment used was the Ab-Slide (Zhejiang Gaoxin Industrial & Trading Co., Ltd., Jinhua, China).

Procedures

Before positioning the electrodes over each muscle, the skin was prepared by shaving, abrading, and cleaning with isopropyl alcohol wipes to reduce skin impedance. Electrode preamplifiers were attached to the subject's skin with double-sided adhesive tape. The tape contained wells that were aligned with the electrodes. Conductive gel was used to fill the wells and to conduct the electrical signal to the electrodes. All electrodes were placed on the subject's right side (Figures 1–4) for the following muscles in accordance with procedures previously described by Cram and Kasman (7) and Ng et al. (14): (a) RA, electrode positioned 2 cm lateral from the midline of the umbilicus; (b) EO, electrode positioned halfway between the most inferior point of the costal margin of the ribs and the anterior superior iliac spine (ASIS) and angled toward the pubic symphysis in a parallel direction to the fibers of the EO; (c) IO, electrode positioned in a horizontal direction within a triangle consisting of a medial border made up of a line from the umbilicus to the pubic symphysis, an inferior border made up of a line from the ASIS to pubis symphysis, and a superior border made up of a line from ASIS to ASIS; and (d) RF, electrode positioned vertically near the midline of the thigh approximately halfway between the ASIS and proximal patella. The ground electrode was positioned over the skin of the right acromion process. Electrode cables were taped to skin to minimize pull on the electrodes and movement of the cables as needed.

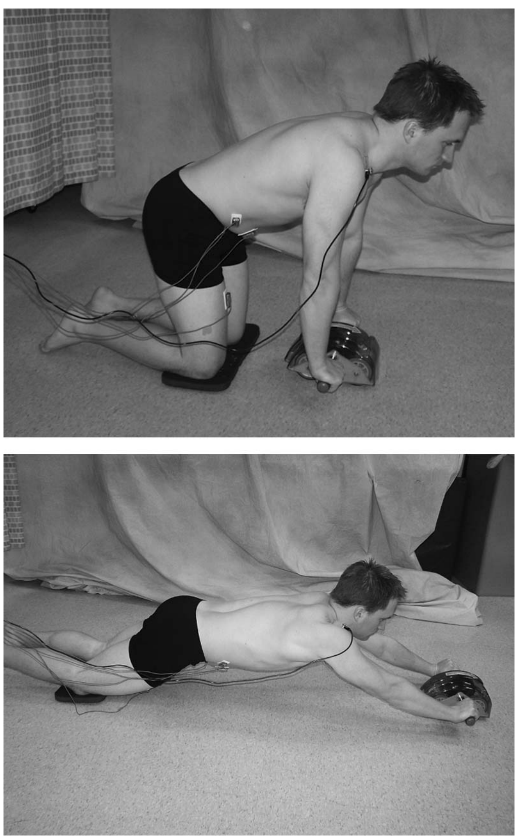


Figure 1. Sample pictures of a subject performing the Ab-Slide exercise, with the starting position (top) and the completion of the roll-out phase (bottom). Subjects held the roll-out position for 1 second before returning to the starting position.

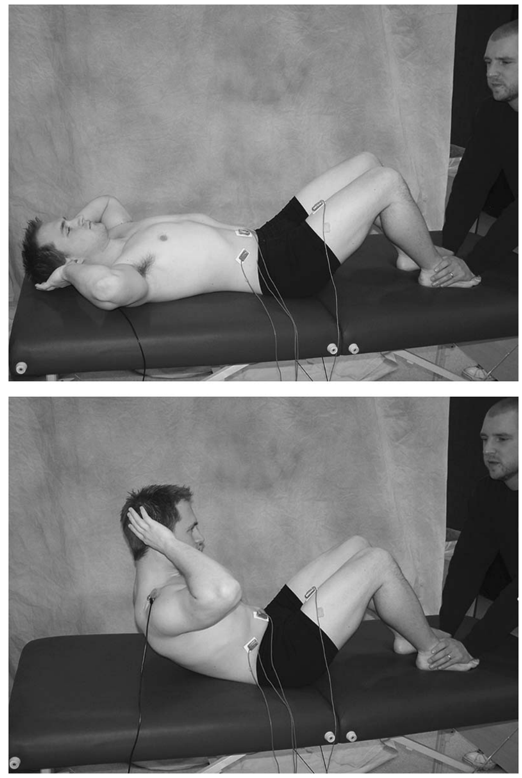
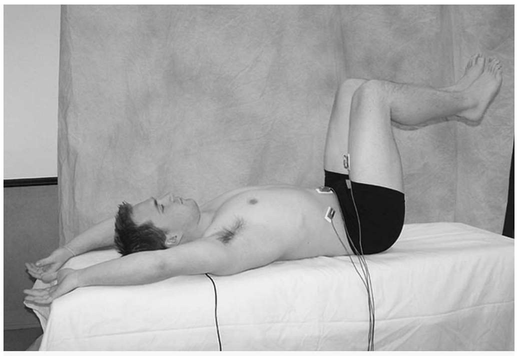


Figure 2. Sample pictures of a subject performing an abdominal crunch exercise with the starting position (top) and the end of the thoracolumbar flexion (bottom). Subjects were instructed to curl the trunk until the inferior angles of the scapulae were lifted off the mat. The end range of thoracolumbar flexion was held for 1 second before the subject returned to the starting position.

On completing the electrode attachment, EMG data from each muscle tested were collected during a 5-second MVIC.



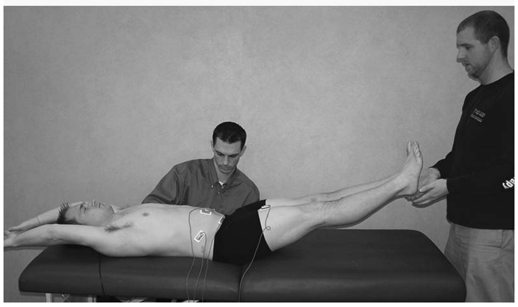


Figure 3. Sample pictures of a subject performing a supine double leg thrust exercise with the starting position (top) and the end of the double leg thrust (bottom). From the starting position, subjects simultaneously extended their hips and knees, similar to the performance of a supine double leg press exercise. The end range of hip extension was predetermined, and the subjects held this position for 1 second before returning to the starting position. During this exercise, the lumbar spine was pressed firmly against the support surface in response to the lumbar extension moment created by the pull of the hip flexor muscles as the thighs extend.

The MVICs were obtained to normalize the EMG data during the abdominal exercises. The protocol for MVIC testing was adopted from Escamilla et al. (7). For the RA, the subject was positioned supine in a hook-lying position with

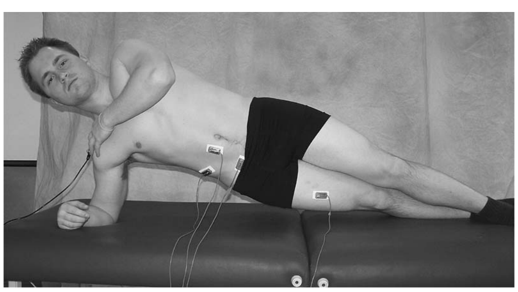


Figure 4. Sample picture of a subject performing the side bridge exercise. Subjects were instructed to hold this position with emphasis on straight alignment of the trunk when viewed from both the sagittal and frontal planes.

the feet supported and the thoracolumbar spine maximally flexed (curl-up position). Manual resistance was applied to the subject's shoulders in the direction of trunk extension. For the EO, the subject was supine in a hook-lying position with feet flat on the support surface. The trunk was maximally flexed and rotated to the left, with manual resistance at the shoulders applied in the direction of trunk extension and right rotation. For the IO muscle, the subject was supine in a hook-lying position with the trunk flexed and maximally rotated to the right. Manual resistance was applied at the shoulders in the direction of trunk extension and left rotation. For the RF, the subject was supine on the table. The action of the RF was tested across the hip and knee simultaneously. The subject's right hip was flexed to 45° with the knee extended. Resistance was applied by the tester on the distal leg just proximal to the malleoli. For each subject, an examiner provided verbal encouragement to maintain a consistent effort during the MVIC. After each MVIC, each subject was queried if he or she believed the effort was a maximum effort. If not, the MVIC was repeated. A 1-minute rest was provided between each MVIC, and a 2-minute rest was given between each exercise trial.

All subjects became familiar with each abdominal exercise during a pretest training session that took place approximately 1 week before the testing session. During the pretest session, each subject received verbal instructions explaining how to correctly perform each of the abdominal exercises. The subjects subsequently practiced all four exercises under the close supervision of trained research personnel. Once the subject correctly performed all four exercises according to the specified cadence, a testing session was scheduled. All subjects performed the exercises, with exception of the side bridge, to a 3-second count. During the first second, subjects moved from the starting position to the end range of the exercise, maintained this end range position throughout second two, and then returned to the initial position during the third second. The side bridge exercise position was held isometrically for a count of 5 seconds. Subjects drew cards to randomly determine the order in which the exercises were to be performed. This randomization was done to minimize threats to the study's internal validity.

The Ab-Slide exercise started and finished in the quadruped position (Figure 1). From the starting position, the subjects gripped the device's handles and rolled forward in a straight line until the forearms nearly touched the floor while the elbows remained in extension. Subjects were instructed to maintain a neutral spine and pelvis throughout the duration of the exercise. Next, the subjects rolled back to the starting position. All subjects accomplished the Ab-Slide roll-out and roll-back without difficulty, which can be attributed to their upper-body muscle performance, core muscle strength, and low percent body fat.

The abdominal crunch exercise started and finished in a hook-lying position (Figure 2). The crunch involved a curling-up motion (thoracolumbar flexion) until both scapulae were lifted from the support surface. From the starting position and throughout the movement, the subject's thumbs were positioned in the ears, and the fingers were relaxed against the head to eliminate excessive flexion of the cervical spine.

The supine double leg thrust exercise started with the subject in supine position with the hips and knees in the 90°-90° position of hip and knee flexion (Figure 3). Subjects were instructed to rest their arms above their head on the table and to contract their abdominal muscles to tilt the pelvis posteriorly and flatten the lumbar spine against the support surface. This maneuver was similar to the performance of a supine double leg press. Firm contact between each subject's low back and the table was monitored by an examiner, who placed his fingertips between the subject's lumbar spine and the surface of the table. During the performance of the supine double leg thrust, subjects were instructed to maintain firm pressure between their low back and the examiner's fingertips. As the subjects extended their hips and knees, the examiner halted the movement at the point where the subject could no longer maintain firm contact between the low back and the examiner's fingertips. At this point, the angle of the thigh in relation to the trunk was recorded by a second examiner using a universal goniometer. This trunk-thigh angle served as a target position for the subject at the end range of the supine double leg thrust (Figure 3). These trunk-thigh angles were 17 ± 8 and 19 ± 13°, respectively, for men and women. During the recorded trials, subjects started the supine double leg thrust in the 90°-90° (hip-knee) position followed by simultaneous extension of the hips and knees until reaching the predetermined target position. As with the other exercises, this motion was performed using a 3-second count.

The side bridge exercise started with the subject lying on the right side with the torso supported by the right forearm and elbow (Figure 4). The lower extremities were staggered with the left foot positioned in front of the right to increase sagittal plane stability. For the purposes of this study, only the right side bridge was examined as the EMG electrodes were only placed over muscles of the right abdominal wall. Subjects were instructed to assume a side bridge position so that the trunk was in neutral alignment when viewed from both the frontal and sagittal planes. Once this optimal position was visually verified by the examiners, the subjects held the position for 5 seconds while data were recorded (Figure 4).

Reliability of Electromyographic Measures

We did not determine the test-retest reliability of the normalized surface EMG data for the RA, EO, IO, and RF muscles during the performance of the four abdominal exercises. Nevertheless, previous investigators have established clinically acceptable test-retest EMG. Shields and Heiss (15) assessed RA, EO, IO, and RF muscle activity during an isometric curl and double straight leg lowering exercise using the intraclass correlation coefficient ($ICC_{3,1}$). For the abdominal curl, ICCs ranged from 0.74 to 0.78, whereas ICC values ranged from 0.73 to 0.79 for the double straight leg raise. Furthermore, Willett et al. (19) examined the test-retest reliability of normalized surface EMG data from the RA and EO muscles for five commonly performed abdominal strengthening exercises under both isometric and dynamic conditions. The $ICC_{3,1}$ values for the isometric conditions ranged from 0.78 to 0.97, whereas the $ICC_{3,1}$ measures for the dynamic conditions ranged from 0.73 to 0.84. On the basis of this information, we believe our EMG activation data would be reliable because we used similar electrode placement and skin preparation procedures as did Shields and Heiss (15) and Willett et al. (19).

Statistical Analyses

We used a two-factor repeated-measures analysis of variance (ANOVA) to assess differences in normalized EMG muscle activity among the different exercise variations ($p \leq 0.05$). Post hoc analyses were performed using the Bonferroni test to assess the significance of between-exercise pair comparisons ($p < 0.002$), whereby an individual was asked to perform four different abdominal exercises while the EMG activity was recorded from the RA, EO, IO, and RF muscles. Independent variables included the four abdominal exercises (Ab-Slide, crunch, supine double leg thrust, and side bridge) and the four muscle groups (RA, EO, IO, and RF). The dependent variable was the normalized peak EMG activity of the RA, EO, IO, and RF muscles. SPSS 15.0 software was used for data analysis (SPSS Inc., Chicago, Ill).

Results

Descriptive data (mean and *SD*) were calculated for each muscle during each of the four exercises. A two-factor repeated-measures ANOVA did not detect a gender effect ($F_{1,20} = 3.0$, $p = 0.10$); hence, the data were collapsed across gender. Normalized EMG for each muscle and exercise are shown in Figure 5. We detected a statistically significant muscle × exercise interaction ($F_{9,189} = 5.8$, $p < 0.001$). Using the Bonferroni post hoc analysis, we detected six between-exercise pair comparisons. These differences are indicated by the brackets shown in Figure 5. The EMG activity of the IO during the Ab-Slide exercise (69.8 ± 55.8% MVIC) exceeded the IO activity during the side bridge exercise (39.4 ± 48.4% MVIC). The EMG activity of the RF during the supine double leg thrust (66.5 ± 88.7% MVIC) exceeded the RF activity during the Ab-Slide (28.1 ± 45.4% MVIC). The EMG activity of the RF during the supine double leg thrust (66.5 ± 88.7% MVIC) exceeded the RF activity during the side bridge (19.5 ±17.1% MVIC). The EMG activity of the RA during the Ab-Slide (79.3 ± 42.5% MVIC) exceeded the RA activity during the side bridge (19.5 ± 17.1% MVIC). The EMG activity of the RA during the supine double leg thrust (68.5 ± 34.1% MVIC) exceeded the RA activity during the side bridge (19.5 ± 17.1% MVIC). Lastly, the EMG activity of the

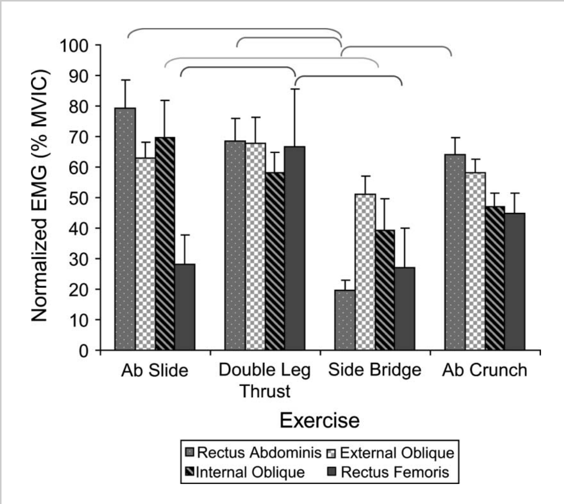


Figure 5. Comparison of the normalized electromyographic (EMG) data (% maximum muscle contraction [MVIC]) for each of the muscles examined for the four different abdominal exercises. The brackets demonstrate a significant post hoc pair difference ($p < 0.002$) when using the Bonferonni-adjusted *t*-test.

RA during the crunch (63.9 ± 27.5% MVIC) exceeded the RA activity during the side bridge (19.5 ± 17.1% MVIC). According to our EMG data obtained from the four exercises, the Ab-Slide exercise induced the greatest abdominal muscle recruitment while minimizing RF muscle activity.

Discussion

The purpose of this study was to examine the effectiveness of the Ab-Slide and more traditional abdominal exercises (crunch, supine double leg thrust, and side bridge) to maximize abdominal (RA, EO, and IO) muscle recruitment while minimizing EMG activity in extraneous musculature (RF). We were able to partially support our research hypothesis because we observed significantly greater EMG activity in the RA and IO muscles during the Ab-Slide exercise when compared with the side bridge. Additionally, we detected significantly less RF EMG activity during the performance of the Ab-Slide than during the supine double leg thrust.

Several recent studies have reported normalized EMG data from abdominal and nonabdominal muscles during the performance of a variety of abdominal exercises. The Ab-Slide (5,9) crunch (1,4,5,9,10) and side bridge (2,10) all have data to support their effectiveness in challenging the abdominal muscles while producing low levels of extraneous (hip flexor) muscle recruitment.

Escamilla et al. (9) tested the effectiveness of seven commercial abdominal machines in addition to the crunch and bent-knee sit-up on activating abdominal and nonabdominal musculature. In contrast, we tested the Ab-Slide and three other abdominal exercises. Data from Escamilla et al. and the present study revealed that the Ab-Slide was the most effective exercise for activating the abdominal muscles while minimizing RF muscle activity. During the Ab-Slide, our normalized EMG activity for the abdominal muscles compared favorably with values reported by Escamilla et al. (9). Escamilla et al. report the largest EMG activity in the RA (72% MVIC), followed by the IO (53% MVIC) and EO (40% MVIC), whereas our values were 80% MVIC (RA), 70% MVIC (IO), and 63% MVIC (EO). Escamilla et al. report only 5% MVIC activity in the RF during the performance of the Ab-Slide, whereas our subjects generated 28% MVIC activity. Perhaps the disparity in RF EMG activity between the two studies during the performance of the AB Slide can be accounted for by the different procedures for measuring the RF MVIC. Escamilla et al. tested their subjects in a short-sitting position with hips and knees flexed to 90°. Manual resistance was applied to the distal leg in the direction of knee flexion, so the RF was tested as a knee extensor. In contrast, we had our subjects in supine position with the right hip flexed to 45° and the knee extended. Resistance was applied to the distal leg in the direction of hip extension and knee flexion. We tested the RF as a hip flexor and knee extensor because the muscle crosses both the hip and knee joints.

Escamilla et al. (9) also report abdominal (RA, EO, and IO) and RF % MVIC muscle activity during the abdominal crunch. Our data show slightly higher activation of the RA (64% MVIC) and IO (47% MVIC) muscles than the values reported by Escamilla et al. (50 and 41% MVIC, respectively). Surprisingly, our data reveal 3.6 times the EO (58% MVIC) muscle activity than the value reported by Escamilla et al. (EO = 16% MVIC) and 15 times more RF (45% MVIC) muscle activity than the near-baseline value reported by Escamilla et al. (RF = 3% MVIC). Andersson et al. (1) also studied activation of the abdominal and hip flexor muscles during various training exercises including the abdominal crunch. Andersson et al. instructed their subjects to perform the crunch in a hook-lying position, but, unlike the study of Escamilla et al. and the present study, subjects performed thoracolumbar flexion with the arms folded across the chest. Andersson et al. also did not normalize their EMG activity according to MVICs; instead, the average EMG amplitude value for each muscle in each exercise was expressed as a percentage of the highest EMG value for that muscle for each subject. Similar to our study, Andersson et al. reported EMG values for the RA and IO of 70 and 52% MVIC, respectively, whereas their subjects only developed 25% MVIC activity of the EO and 9% MVIC activity of the RF. Because the EO and IO muscles both function to control the distance between the xiphoid process and the pelvis during the flexion and extension phases of the crunch, we would anticipate similar EMG activity (10). Furthermore, we also would have expected both Escamilla et al. (9) and Andersson et al. (1) to report greater EMG activity in the RF muscle during the crunch, because the RF acts as a stabilizer to prevent backward tilting of the pelvis due to the tension developed in the RF, EO, and IO muscles (13). We believe the difference in % RF MVIC activity can be accounted for by the MVIC procedure for normalizing the EMG activity.

A novel feature of this study was examination of the EMG activity of the abdominal and hip flexor muscles during performance of the supine double leg thrust. Shields and Heiss (15) previously studied the double straight leg lowering maneuver, which is similar to our supine double leg thrust. The supine double straight leg lowering exercise is considered an advanced exercise for the abdominal muscles. Whereas the abdominal curl examines the ability of the abdominal muscles to flex the thoracolumbar spine against the fixed pelvis, the supine double straight leg lowering test examines the ability of the abdominal muscles to fix the pelvis in a posteriorly tilted position against an external load provided by the lower extremities as they are lowered from a near-vertical starting position. The present study's normalized RA (69% MVIC) and IO (58% MVIC) EMG values were comparable with those reported by Shields and Heiss (15) for the RA (85% MVIC) and IO (65% MVIC) muscles. However, Shields and Heiss's reported EO muscle activity exceeded 120% of the curl MVIC during performance of the supine double straight leg lowering maneuver. In comparison, we reported normalized EO EMG activity of 68% MVIC for the double leg thrust. Because both leg lowering exercises required isometric activation of the EO muscles to keep the pelvis and lumbar spine flattened against the support surface, we suspect the two procedures had some minor methodological differences. Shields and Heiss recorded the EO muscle activity for 5 seconds at the point where the subject could maintain the pelvic position in posterior rotation, whereas we recorded peak EO EMG activity during the dynamic lowering/thrusting of the lower extremities. Although Shields and Heiss did not measure RF EMG muscle activity during supine double straight leg lowering, we found the RF muscle to generate 67% of its MVIC during the double leg thrust. Of the four exercises, the supine double leg thrust created the greatest demand on the hip flexors.

The side bridge exercise performed in our study was identical to the isometric side support exercise examined by Juker et al. (10). Juker et al. report the highest EMG activity in the EO (43% MVIC), followed by the IO (36% MVIC), RA (22% MVIC), and the RF (11% MVIC), whereas our values were 51% MVIC (EO), 39% MVIC (IO), 20% MVIC (RA), and 28% MVIC (RF). Overall, in this study the normalized abdominal muscle EMG activity recorded during the performance of the isometric side bridge was lower than the activity shown in the Ab-Slide, crunch, and supine double leg thrust exercises.

When considering abdominal strengthening, our results found that the Ab-Slide yielded the greatest abdominal activation while minimizing the monitored extraneous musculature activation (RF). It should be noted, however, that this one exercise may not be the most appropriate abdominal exercise for every individual. Because of the limited number of channels available on our EMG amplifier, we were not able to monitor extraneous muscles other than the RF. Therefore, we cannot extrapolate on the demands placed on other muscles during the performance of the exercise. On the basis of the verbal reports of our subjects, the Ab-Slide placed a high demand on the muscles of the shoulders and back and increased the compressive forces throughout the spine. The Ab-Slide may not be an appropriate exercise, however, for persons with spine and upper-extremity impairments.

The side bridge resulted in the lowest overall EMG activation of the abdominals, a potentially attractive feature. This exercise may be a suitable option for individuals with an unstable spine, acute low-back pain, or those recovering from spine surgery. This is true because the spine is held in a neutral position throughout the exercise, and the compressive forces throughout the spine can be assumed to be lower than the Ab-Slide, crunch, and supine double leg thrust because of the absence of active trunk flexion or extension (10). The low activity of both the RA and the RF reduces the rotational torques on the pelvis in the sagittal plane. Although we were unable to monitor the transversus abdominis, this muscle often works in unison with the abdominal obliques to help stabilize the spine. A few investigators (2,10) have described the EMG activity of abdominal and back muscles during the side bridge, yet this exercise is not as popular as the abdominal crunch.

Two methods of sampling exist for the use of quantifying EMG data. We chose to use the peak EMG technique as compared with other studies that have analyzed average EMG obtained during a 0.5-second epoch around the peak EMG value (9). We were not aware of any overwhelming advantages or disadvantages for using either method, so we chose to use the peak value because we felt this would give us the best picture of the muscle activity during the exercises.

In the future, this study would be optimally completed by using an EMG amplifier with additional input channels and with the possibility of using fine-wire electrodes in addition to surface electrodes. This would allow us to monitor activity in additional extraneous musculature and, potentially, the activity of the transversus abdominis, one of the prime lumbar stabilizers. Because the supine double leg thrust is an unexplored exercise, it also would be advantageous to further examine performance of additional extraneous (nonabdominal) musculature including the erector spinae, multifidus, and latissimus dorsi muscles.

One might question the meaningfulness of our EMG activation data for the abdominal muscles by arguing that they could be exaggerated if the exercises were performed for the first time. We contend that our subjects were very familiar with the abdominal crunch, side bridge, and supine double leg thrust exercises. First, all subjects had to correctly perform these exercises under the scrutiny of research personnel at least a week before the formal data-collection session. Additionally, all subjects self-reported that they performed regular personal fitness programs that included abdominal muscle strengthening exercises. Of the four abdominal exercises, the Ab-Slide was the most novel, yet all our subjects were judged competent in performing both the roll-out and roll-back maneuvers while maintaining a neutral lumbar spine.

Practical Applications

Significant differences in muscle activity were observed between exercises in this study. We found that the Ab-Slide exercise was the most effective in activating the abdominal musculature while minimizing the input of the RF muscle. The supine double leg thrust did yield high activation of the RF, so it may not be ideal for patients with low-back pain because of the potential for sagittal plane torques about the pelvis and lumbar spine. These exercises, along with the side bridge, are all effective in activating the abdominal musculature and can be implemented in exercise programs as directed by properly trained physical fitness and medical rehabilitation professionals.

References

1. Andersson, EA, Nilsson, J, Ma, Z, and Thorstensson, A. Abdominal and hip flexor muscle activation during training exercises. *Eur J Appl Physiol* 75: 115–123, 1997.
2. Axler, CT and McGill, SM. Low back loads over a variety of abdominal exercises: searching for the safest abdominal challenge. *Med Sci Sports Exerc* 29: 804–810, 1998.
3. Balady, GJ, Franklin, BA, Whaley, MH, and Howley, ET. *ACSM's Guidelines for Exercise Testing and Prescription* (6th ed.). Philadelphia: Lippincott Williams & Wilkins, 2000.
4. Behm, DG, Leonard, AM, Young, WB, Bonsey, WA, and MacKinnon, SN. Trunk muscle electromyographic activity with unstable and unilateral exercises. *J Strength Cond Res* 19: 193–201, 2005.
5. Bird, M, Fletcher, KM, and Koch, AJ. Electromyographic comparison of the ab-slide and crunch exercises. *J Strength Cond Res* 20: 436–440, 2006.
6. Clark, KM, Holt, LE, and Sinyard, J. Electromyographic comaprison of the upper and lower rectus abdominis during abdominal exercises. *J Strength Cond Res* 17: 475–483, 2003.
7. Cram, JR and Kasman, GS. *Introduction to Surface Electromyography.* Gaithersburg: Aspen Publishers, Inc., 1998.
8. Demont, RG, Lephart, SM, Giraldo, JL, Giannantonio, FP, Yuktanandana, P, and Fu, FH. Comparison of two abdominal training devices with an abdominal crunch using strength and EMG measurements. *J Sports Med Phys Fitness* 39: 253–258, 1999.
9. Escamilla, RF, McTaggert, MSC, Fricklas, EJ, Kelleher, P, Taylor, MK, Hreljac, A, and Moorman, CT. An electomyographic analysis of commercial and common abdominal exercises: implications for rehabilitation and training. *J Orthop Sports Phys Ther* 36: 45–57, 2006.
10. Juker, D, McGill, S, Kropf, P, and Steffen, T. Quantitative intramuscular myoelectric activity of lumbar portions of psoas and the abdominal wall during a wide variety of tasks. *Med Sci Sports Exerc* 30: 301–310, 1998.
11. Lohman, TG, Houtkooper, LB, and Going, SB. Body composition assessment: body fat standards and methods in the field of exercise and sports medicine. *ACSM Health Fitness J* 1: 30–35, 1997.
12. McGill, S. *Low Back Disorders: Evidence-Based Prevention and Rehabilitation.* Champaign: Human Kinetics, 2002.
13. Neumann, DA. *Kinesiology of the Musculoskeletal System: Foundations for Physical Rehabilitation.* St. Louis: Mosby, 2002.
14. Ng, JFK, Kippers, V, and Richardson, CA. Muscle fibre orientation of abdominal muscles and suggested EMG electrode positions. *Electromyogr Clin Neurophysiol* 38: 51–58, 1998.
15. Shields, RK and Heiss, DG. An electromyographic comparison of abdominal muscle synergies during curl and double straight leg lowering exercises with control of the pelvic position. *Spine* 22: 1873–1879,1997.
16. Sternlicht, E and Rugg, S. Electromyographic analysis of abdominal muscle activity using portable abdominal exercise devices and a traditional crunch. *J Strength Cond Res* 17: 463–468, 2003.
17. Warden, SJ, Wajswelner, H, and Bennell, KL. Comparison of Abshaper and conventionally performed abdominal exercises using surface electromyography. *Med Sci Sports Exerc* 31: 1656–1664, 1999.
18. Whiting, WC, Rugg, S, Coleman, A, and Vincent, WJ. Muscle activity during sit-ups using abdominal exercise devices. *J Strength Cond Res* 13: 339–345, 1999.
19. Willett, GM, Hyde, JE, Uhrlaub, MB, Wendell, CL, and Karst, GM. Relative activity of abdominal muscles during commonly prescribed strengthening exercises. *J Strength Cond Res* 15: 480–485, 2001.