
ELECTROMYOGRAPHIC RESPONSE OF THE ABDOMINAL MUSCULATURE TO VARYING ABDOMINAL EXERCISES

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ABSTRACT

Schoffstall, JE, Titcomb, DA, and Kilbourne, BF. Electromyographic response of the abdominal musculature to varying abdominal exercises. *J Strength Cond Res* 24(12): 3422–3426, 2010—This study examined the electromyographic (EMG) response of the upper rectus abdominis (URA), lower rectus abdominis (LRA), internal obliques (IOs), external obliques (EOs), and the rectus femoris (RF) during various abdominal exercises (crunch, supine V-up, prone V-up on ball, prone V-up on slide board, prone V-up on TRX, and prone V-up on Power Wheel). The subjects ($n = 21$) performed an isometric contraction of the abdominal musculature while performing these exercises. Testing revealed no statistically significant differences between any of the exercises with respect to the EOs, the URA, or the LRA. However, when examining the IO muscle, the supine V-up exercise displayed significantly greater muscle activity than did the slide exercise. In addition, EMG activity of the RF during the crunch was significantly less than in any of the other 5 exercises. These results indicate that when performing isometric abdominal exercises, non-equipment-based exercises stressed the abdominal muscles similarly to equipment-based exercises. Based on the findings of the current study, the benefit of training the abdominal musculature in an isometric fashion using commercial equipment could be called into question.

KEY WORDS EMG, lower abs, core stabilization

INTRODUCTION

Core strengthening has long been known as a key component of athletic conditioning and performance (8). The abdominal musculature is considered to be 1 of 5 components that make up the “core” of an individual. The other regions include the musculature of the hip, lumbar spine, thoracic spine, and cervical spine (7). Prior research has shown that

strengthening the abdominal musculature (rectus abdominis, external oblique [EO], internal oblique [IO], and transverse abdominis [TA]), through dynamic exercise, can not only increase core stabilization but can also improve muscle coordination and prevent injury (2,19). The abdominal muscles also ensure the proper function of the lumbar spine (10,17). Although all of the abdominal muscles contribute to lumbar spine stabilization, the TA and IOs have been shown to be the primary stabilizers (14,15).

Because of contradicting research results, one of the biggest challenges facing coaches, athletic trainers, and rehabilitation professionals is choosing and implementing an appropriate exercise, which could be either a static or dynamic exercise, to target a specific abdominal muscle or muscle group (18). For example, when analyzing which portion of the rectus abdominis is active in a reverse crunch, Sarti (16) found that the lower rectus abdominis (LRA) produced greater electromyographic (EMG) output than the upper rectus abdominis (URA). However, others (3,21) concluded that there were no significant differences between the EMG outputs in the LRA vs. URA in a reverse crunch. In addition, Juker et al. (10) who investigated abdominal wall musculature during 27 different tasks concluded that 1 specific abdominal exercise that activates all 4 abdominal muscles at the same time has not been found to exist.

Often, abdominal strengthening devices are promoted on television to be superior to the traditional abdominal crunch or sit-up exercises to improve strength and body image (9). Over the last 2 decades, there has been an overabundance of advertisements promoting the sales of abdominal strengthening devices; however, there are only a small number of EMG studies published in scientific literature that test some of these devices (5). Surface EMG (SEMG) recording has been shown to be an effective means to research the relative amount of muscle activity in various muscles and provide information regarding the timing and coordination of muscle activity (9).

The purpose of this study was to compare SEMG activity of the URA, LRA, IO, EO, TA, and the rectus femoris (RF) during varied abdominal strengthening exercises in 20 healthy subjects. The exercises consisted of both the traditional crunch and nontraditional abdominal exercises. The nontraditional exercises used devices including the Ab Slide, TRX (TRX), Fitness ball (FB), and Power Wheel (PW).

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We hypothesized that varying traditional and nontraditional abdominal exercises would not produce any significantly different muscular activity as measured by SEMG.

METHODS

Experimental Approach to the Problem

This study was designed to test the hypothesis that varying V-up exercises: supine V-up, prone V-up using a stability ball, prone V-up using a slide board, prone V-up using the TRX device, and the prone V-up using a foot wheel will not produce any significantly different muscular activity as measured by SEMG. The independent variables included the 5 previously mentioned abdominal exercises. The dependent variable was the root mean square (RMS) peak EMG activity of the 5 tested muscles: URA, LRA, EO, IO, and RF.

Subjects

Subjects ($n = 21$) were recruited via word of mouth. The characteristics of the subjects were (mean \pm SD): age 20.5 ± 1.5 years, height 177.6 ± 7.5 cm, weight 75.205 ± 11.684 kg, body fat $12.4 \pm 5.0\%$ for the men ($n = 11$), and age 20.6 ± 1.2 years, height 166.5 ± 5.8 cm, weight 55.806 ± 6.787 kg, body fat $17.0 \pm 4.9\%$ for the women ($n = 10$). The subjects were active and risk stratified as being low risk according to the American College of Sports Medicine guidelines (1). Procedures for the study were explained, and informed consent was obtained from each subject. This study was approved by the institutional review board.

Procedures

Height was measured to the nearest 0.1 cm using a scale-mounted stadiometer (SECA model 220, Hamburg, Germany). Subjects were measured without shoes with hands by their sides, while standing erect and completing a maximal inspiration. After subjects had voided both their bladder and bowels, body weight was measured to the nearest 0.001 kg using a calibrated digital platform load cell (Tanita Corp., BWB-627-A, Tokyo, Japan). Body composition was measured using the air-displacement plethysmography method (BOD POD®, Life Measurement Instruments, Concord, CA, USA) using published procedures (4,13).

After the body composition testing, the participants were instructed on how to correctly perform the 6 abdominal exercises: crunch, supine V-up, prone V-up using an FB (Century Martial Arts, Oklahoma City, OK, USA), prone V-up using a Power Slide (Athletic Innovation, Inc., Rochester, NH, USA), prone V-up using the TRX Suspension Trainer (Fitness Anywhere, San Francisco, CA, USA), and the prone V-up using a Power Wheel™ (LifelineUSA, Madison, WI, USA). After the subjects demonstrated that they could correctly perform the exercises they were scheduled to come back to the laboratory for the EMG testing.

Before positioning the electrodes over the muscle sites, the skin was prepared by shaving, abrading, and cleaning with isopropyl alcohol wipes. The raw EMG signals were obtained

with DE-2.1 Standard Differential EMG Surface Electrodes (Delsys Inc., Boston, MA, USA) in conjunction with the Bagnoli™ Desktop EMG System and EMGworks® Signal Acquisition and Analysis software. The electrode assembly measured $41 \times 20 \times 5$ mm. The DE-2.1 unit consists of a silver parallel bar configuration, in which the bars are set 10.0 mm apart and are 10.0 mm in length and 1.0 mm in width. The electrodes have preamplified gain of 10 V/V. The electrodes were secured to the sites using double sided, 2-slot electrode tape (SC-Fo1-2 Slot Interface, Delsys Inc.). The 5 electrode lines and the reference line were directly connected to an Input Module (DS-80-IM, Delsys Inc.), which was secured to the subject waist band via a metallic clip.

The ground electrode was placed over the right acromion process. The surface electrodes were placed on the right side of the body at the 4 sites that follow: URA, 2 cm lateral and 5 cm superior from the midline of the umbilicus; LRA, 2 cm lateral and 5 cm inferior from the midline of the umbilicus IO, in a horizontal direction within a triangle consisting of the medial border made up on a line from the umbilicus to the pubic symphysis, and a superior border made up of a horizontal line from the anterior superior iliac spine (ASIS) to ASIS, and an inferior border made up of a line from the ASIS to pubis symphysis; EO, halfway between the most inferior point of the costal margin of the ribs and the ASIS; and RF, vertically near the midline of the anterior aspect of the thigh halfway between the ASIS and the superior border of the patella (5).

After the electrodes were in place, the subject drew exercise cards to randomize the order of exercise performance. The technique used in performing the exercises were as follows: (a) *Crunch*: the subject assumed a supine position on the floor, the knee joint was set at 90° , and the arms were crossed over the chest. When prompted, the subject lifted his upper body off of the floor as high as possible, while still maintaining floor contact with the lower back. The shoulder-hip-knee angle (SHKA) was approximately 100° (Figure 1). (b) *Supine V-up*:



Figure 1. Crunch.



Figure 2. Supine V-up.

the subject assumed a supine position on the floor, with the arms resting by the subject's sides. When prompted, the subject lifted his upper body and legs off of the floor; reaching toward the feet with the hands, while maintaining a balance on the gluteus. The SHKA was maintained at 90° (Figure 2). (c) *Prone V-up using an FB*: the subject assumed a prone position, with the arms extended and hands positioned slightly in front of the shoulders; the legs were positioned on top of the FB, with the mid-tibia positioned directly on top of the ball. When prompted, the subject went into the prone V-up position by rolling the ball toward the hands until the subject's toes were contacting the ball. The SHKA was maintained at 90° (Figure 3). (d) *Prone V-up using a Power Slide*: the subject assumed a prone position, with the arms extended and the hands positioned slightly in front of the shoulders and off of the surface of the slide; the legs were extended back with sliding booties on the feet. When prompted, the subject went into the prone V-up position by sliding the feet up the Power Slide surface toward the hands until the SHKA was at 90° (Figure 4). (e) *Prone V-up using*



Figure 4. Prone V-up on the power slide.

a TRX Suspension Trainer: the TRX was suspended from power rack and the stirrups were adjusted so that the bottom of the stirrup was 10 cm above the floor surface. The subject assumed a prone position, with the arms extended and the hands positioned slightly in front of the shoulders, and the legs were extended back with the feet secured into the stirrups. When prompted, the subject went into the prone V-up position by pulling the feet toward the hands until the SHKA was at 90° (Figure 5). (f) *Prone V-up using a Power Wheel™*: the subject assumed a prone position, with the arms extended and the hands positioned slightly in front of the shoulders, and the legs were extended back with the feet secured into the stirrups of the PW. When prompted, the subject went into the prone V-up position by pulling the feet toward the hands until the SHKA was at 90° (Figure 6).

Once the subject was in the proper position, EMG data were collected during a 5-second maximal voluntary isometric contraction (MVIC). After each MVIC, the subject was questioned as to whether he or she believed the effort was a maximum effort. If not, the MVIC was repeated. A 1-minute



Figure 3. Prone V-up on the fitness ball.



Figure 5. Prone V-up on the TRX.



Figure 6. Prone V-up on the power wheel.

rest was provided between each MVIC, and a 2-minute rest was given between each exercise trial.

Statistical Analyses

An analysis of variance was used to assess the differences in the EMG activity of the muscles associated with the various exercises. The criterion for significance was $p \leq 0.05$, with a Bonferroni adjustment ($0.05 \div 15$ pairwise comparisons) of ≤ 0.00333 for post hoc pairwise comparisons. Independent variables included the 5 muscles (RF, URA, LRA, IO, and EO) and the 6 exercises (crunch, supine V-up, prone V-up using an FB, prone V-up using a Power Slide, prone V-up using the TRX Suspension Trainer, and the prone V-up using a Power WheelTM). The dependent variable was the RMS peak EMG activity of the RF, URA, LRA, IO, and EO muscles. SPSS 16.0 software was used for data analysis (SPSS Inc., Chicago, IL, USA).

RESULTS

Descriptive data were computed for the 5 muscles on each of the 6 exercises. Raw EMG data for each muscle and exercise are displayed in Figure 1. There were no statistically significant differences between any of the 6 exercises when measured using the EO muscle, the URA, or the LRA. When examining the IO muscle, there was a statistically significant difference ($p = 0.002$) in the muscle activity for the Slide ($89.73 \pm 88.87 \mu V$) and the supine V-up ($138.26 \pm 81.01 \mu V$). The muscle activity of the RF during the crunch ($11.26 \pm 5.28 \mu V$) was statistically significantly less ($p < 0.001$) than in any of the other 5 exercises (Ball: $45.71 \pm 42.76 \mu V$; TRX: $56.49 \pm 29.18 \mu V$; Wheel: $40.47 \pm 19.52 \mu V$; Slide: $27.52 \pm 16.08 \mu V$; V-up: $40.83 \pm 17.70 \mu V$). Based on the EMG readings, the crunch caused the most focused muscle activity of the abdominal musculature, while limiting the activity of the RF. Although significantly different from the other exercises the prone V-up using the wheel produced the greatest amount of overall muscular activity.

DISCUSSION

The intention of this study was to compare the SEMG activity of the URA, LRA, IO, EO, TA, and RF, to determine if varying abdominal exercises would produce significantly different muscular involvement, as measured by SEMG, among the muscles of the abdomen. As hypothesized, the results of this study showed no statistically significant difference in the muscle activity of the EO, RF, URA, and the LRA during the 6 abdominal exercises. These findings are similar to those of Kasee and Noble (11). Kasee and Noble (11) argue that the exercises with a high degree of difficulty resulting from hip motion or stability such as exercises performed on exercise balls fail to isolate the abdominal muscles and result in high activity of the EO and firing of the RF. This argument is supported this research study because all but 1 exercise tested had high degrees of difficulty because of required hip flexion, stabilization of the body, or a combination of both.

To further support the authors' hypothesis, no significant differences between the URA and LRA were found during any of the abdominal exercise tested. These results are in agreement with the results of several previous studies (3,5,12) that found no significant differences between the URA and LRA during any of the abdominal exercise tested. It is important to note that several studies (16,18,20) have found differences in the muscle activity during given abdominal exercises. Even Clarke et al. (3) who ultimately showed no difference in the muscle activity of the 2 portions of the rectus abdominis stated that although not statistically significant there was a trend toward higher EMG amplitudes in the URA as compared with the LRA during those exercises that are typically used to "target" the upper abdominals. The only exception occurred during the reverse curl-up in which the trend showed higher LRA activity. Kasee and Noble (11) also found no significant difference in the activity of the URA and the LRA. They speculated that the lack of significant results could be a result of the positioning of the LRA beneath the aponeuroses of the internal and EOs and the TA creating cross-talk between leads of the EMG.

This study demonstrated statistically significant involvement of the IOs during the slide and the supine V-up, which disproves the current study's hypothesis when using it to explain these 2 exercises. Floyd and Silver (6) state that the IO electrode may pick up from the lowest fibers of the transversus abdominis because of the similarity of origin, course, and insertion, which could potentially explain the current results.

It is important to understand which exercises will elicit activity in the abdomen as opposed to the RF because the RF is a hip flexor and not a spinal stabilizer or spinal flexor. The results of this showed that the only exercise that limited the activity of the RF while producing the most focused muscle activity in the abdomen was the abdominal crunch. This is essential to note because activity of the RF results in an

anterior rotation of the pelvis, thereby increasing the lordosis of the lumbar spine. The anterior rotation of the pelvis can be problematic for individuals with a history of back pain.

This study found that the prone V-up using the wheel produced the greatest amount of overall muscle activity. These results of this study support the findings of both Youdas et al. (22) and Escamilla et al. (5) who conducted studies using devices similar to the PW. Youdas et al. (22) used an Abslide®, whereas Escamilla et al. (5) used a hand-held abdominal exercise wheel. The major difference between the Abslide® and the hand-held wheel devices and the foot wheel is that the trunk and the arms are the lever as opposed to the legs.

Although the information found in this study should certainly be considered when selecting equipment and exercises for athletes or clients, it is important to remember that only MVIC was measured. Therefore, information is limited to 1 point in the range of motion. Areas for future research should focus on muscle activity during dynamic exercises.

PRACTICAL APPLICATIONS

The strength of the abdominal musculature plays an important role in the stabilization of the spine, muscle coordination, and injury prevention and therefore is a crucial aspect of a comprehensive strength and conditioning program (2,19). Although many practitioners hold the belief that certain exercises can isolate particular portions of the abdominal muscles, this may not be the case. To apply the findings from this study, practitioners should focus on overall muscle activity as opposed to what abdominal muscles they believe are being worked. Out of the 5 exercises performed, the prone v-up produced the most muscle activity and is therefore a very efficient exercise to overload the muscles.

The information in this study is also useful when considering what equipment should be purchased for programs or for personal use. The crunch and the prone v-up tested equal to or better than the exercises that used the commercially available equipment. Based on these findings, it would be recommended that the strength and conditioning practitioner closely evaluate the need for using additional equipment when performing static abdominal work.

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