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Electromyographic Analysis of Abdominal Muscle Activity Using Portable Abdominal Exercise Devices and a Traditional Crunch

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ABSTRACT

The purpose of this study was to compare the abdominal muscle activity elicited while using 4 portable abdominal training devices vs. a traditional crunch. Thirty-three adults participated in this study. The exercise devices tested included the Ab Roller Plus, Torso Track 2, AB-DOer Pro, and the Perfect Abs. All subjects were tested on the Perfect Abs in both a seated and supine position using low-, medium-, and high-resistance bands. The Torso Track 2 was also tested at low- and high-resistance settings. Surface electromyography (EMG) was recorded from the upper and lower portions of the rectus abdominis, external oblique, and the rectus femoris during each repetition. Statistical analyses were performed on the mean EMG values using a repeated analysis of variance (ANOVA) procedure. There was no significant difference in abdominal muscle activity between the Ab Roller Plus, the Torso Track 2 (high resistance), and a traditional crunch. The mean abdominal muscle activity was significantly lower than a normal crunch, however, when using the AB-DOer, Torso Track (low resistance), and the Perfect Abs seated with the low-resistance band. In contrast, the Perfect Abs, when used in the supine position with the medium- and high-resistance bands, elicited significantly greater mean abdominal muscle activity than a crunch. Of the 4 devices tested, only the Perfect Abs when used in the supine position with the medium- and high-resistance bands, elicited more abdominal activity than a crunch. The results suggest that portable abdominal devices are most effective if they not only mimic the mechanics of a traditional crunch, but also provide external resistance to increase the involvement of the abdominal musculature.

Reference Data: Sternlicht, E., and S. Rugg. Electromyographic analysis of abdominal muscle activity using portable abdominal exercise devices and a traditional crunch.

Key Words: crunches, resistance exercise, muscle recruitment, biomechanics.

Introduction

Resistance training exercises are designed to overload specific muscles in order to increase muscular strength and/or endurance. Therefore, one of the greatest challenges trainers, therapists, and physicians face is the selection of appropriate exercises and variations in equipment to best isolate a targeted muscle or muscular region. An integral component of most training programs is the use of exercises to increase abdominal strength. For example, crunches (curl-ups), sit-ups, leg raises, and the use of abdominal training devices are all used to increase abdominal strength, enhance performance, and reduce the risk of lower-back injury. In recent years numerous companies have capitalized on this trend by developing portable abdominal exercise devices. Despite manufacturer claims that their abdominal devices are superior to a crunch, published research fails to support these statements .

A common technique for determining a muscle's relative involvement during an exercise is to record its electrical activity using electromyography (EMG). Numerous EMG studies have been performed to assess the involvement of the anterior trunk muscles during various types of abdominal exercises . For example, Sarti et al. reported greater activation of the lower portion of the rectus abdominis when their subjects performed a reverse crunch compared with a traditional crunch. Whiting et al. (19) demonstrated that activation of the upper and lower portions of the rectus abdominis and external oblique were influenced by whether their subjects performed a traditional, oblique, or reverse crunch.

Since the principal reason for performing a crunch, or sit-up, is to train the abdominals and not the hip flexors, the motion should be performed to minimize hip flexor activity. In contrast to a sit-up, a crunch is typically performed by lifting only the head and shoulder blades off the floor. This not only minimizes lumbar motion, but also reduces psoas activation, and therefore reduces the compressive and shear stress on the lumbar vertebra. Research focusing more specifically on the sit-up has shown that although some subjects show iliacus activity throughout the full sit-up, the greatest activity typically occurs after the first 30? (2, 5). According to Travell and Simons , some subjects used the rectus femoris with minimal to no iliacus activity, whereas others used both to initiate the sit-up. Similarly, Juker et al. reported that the sit-up exercises tested activated the psoas between 15 and 35% of its maximal voluntary contraction (MVC), whereas the curl-up (crunch) exercises tested recruited the psoas less than 10% of its MVC. Based on the sit-up? and curl-up?type exercises tested by Juker et al. , the curl-up (or cross-curl) was the best exercise for challenging the abdominal muscles (rectus abdominis, external and internal oblique, and transverse abdominis) and minimizing the compressive and shear stress on the lumbar vertebra induced by psoas activation. Because of the effectiveness of the crunch in recruiting the abdominal muscles, in reducing hip flexor activity and reducing lumbar stress, the crunch has become a popular training exercise and the standard to which portable abdominal devices are compared.

The purpose of this study was to compare the abdominal muscle activity elicited using 4 abdominal exercise devices with the muscle activity recorded during a traditional crunch in order to determine if the claims made by the manufacturers are supported by the current research.

Methods

Experimental Approach to the Problem

In this study we wanted to determine if the 4 abdominal devices used are as effective at recruiting the abdominal muscles as a traditional crunch. Mean EMG recordings from the upper and lower portions of the rectus abdominis and external oblique from 33 subjects provided the data needed to evaluate the effectiveness of each device. To ensure valid comparisons in our EMG data, range of motion (ROM) and velocity of movement were controlled across devices and subjects. Over years of testing numerous abdominal devices, we have found that our male and female subjects produced similar abdominal activity patterns across devices. For that reason we did not separate the data by gender.

Subjects

Thirty-three healthy adult volunteers (20 men and 13 women) participated in this study. The subjects mean ? standard deviation for age, height, and body mass were 27.3 ? 10.7 years, 68.7 ? 4.4 inches, and 150.2 ? 33.7 pounds, respectively. Subjects were instructed on how to use each device and perform each exercise properly prior to collecting data. After receiving an explanation of the experimental protocol, each subject practiced the proper technique for using each device and signed a university-approved informed consent form. Subject selection was limited to individuals with sufficiently low subcutaneous adipose tissue in order to permit accurate measurement of muscle activity.

Exercise Devices

Four portable exercise devices were tested. These devices included the Ab Roller Plus (Quantum North America, Glendale, CA), Torso Track 2 (Fitness Quest, Inc., Canton, OH), AB-DOer Pro (Thane Fitness, La Quinta, CA), and the Perfect Abs (Guthy-Renker, Santa Monica, CA).

The Ab Roller Plus consists of tubular construction shaped to roll forward and backward as the person performs a crunch motion. The Torso Track 2 is a variable resistance device based on the fundamental principle of the roller wheel that requires the user to perform the movement in a kneeling position. The AB-DOer requires the user to be seated with his or her arms abducted to approximately 90? and the elbows flexed to enable the user to grasp the handles while performing various truck movements. The Perfect Abs is a banded device that spans the abdominal region with one end supported on the thighs and the other held with the hands at chest level. Three bands were provided for testing. Each band is inserted, one at a time, into the thigh and hand components. The bands vary in thickness, allowing for variable resistance to be applied while performing a crunch motion.

Experimental Design

After appropriate instruction on the proper technique for using each device and for executing a proper crunch, subjects performed 1 set, 8?10 repetitions per set, for each abdominal exercise. Since most portable abdominal devices mimic the mechanics of performing a crunch and not a sit-up, this study used the traditional crunch as the criterion measure. All subjects were tested on the Perfect Abs in both a seated and supine position using low-, medium-, and high-resistance bands and on the Torso Track 2 using low- and high-resistance settings. Condition testing order was randomized across subjects. All data for each subject were collected during a single session.

To ensure temporal consistency, each subject was instructed to perform each set with a given device through a constant ROM and at a constant speed during the concentric and eccentric phase. A metronome was used to pace each phase of the movement at a rate of 1.5 seconds per phase (concentric and eccentric). Sufficient rest was allowed between trials to avoid fatigue. None of the subjects commented that they felt fatigued at any point during their data collection session. The EMG activity was assessed for 5 consecutive crunches in each set. The criterion measure was the mean EMG value for each set.

In the traditional crunch, hips and knees were flexed to approximately 90? with the hands clasped behind the head. Each subject was instructed to flex his or her trunk so the head and shoulders, and therefore scapulas, would clear the mat. The same instructions were used for the Ab Roller Plus and the Perfect Abs (supine position), with the exception that the hands were on the handles of each device instead of behind the head. Starting from a vertical position, the same crunch motion was also performed using both the AB-DOer and the Perfect Abs (seated position).

EMG Recording

Muscle activity was measured using a standard noninvasive EMG system (BIOPAC Systems, Inc., Goleta, CA). Bipolar silver-silver chloride surface electrodes (EL208S, BIOPAC) were placed on the skin overlying the right upper portion of the rectus abdominis (URA), right lower portion of the rectus abdominis (LRA), right external oblique (EO), and the right rectus femoris (RF). An unshielded ground electrode (EL208, BIOPAC) was placed on the skin overlying the acromion process. The electrodes were oriented parallel to the muscle fibers with an interelectrode distance of approximately 1.5 cm. Prior to electrode application, the skin over each muscle was shaved and cleansed with alcohol to reduce the impedance at the skin electrode interface. EMG signals were sampled at 1,000 Hz per channel and amplified (gain of 5,000) and band-pass filtered (10?400 Hz) using BIOPAC Systems amplifiers. Signals were then passed through a BIOPAC Systems Model MP100 connected to an IBM i1200 laptop computer for analysis.

Statistical Analyses

Statistical analyses using the SPSS program, version 10, were performed on the mean EMG values using a repeated-measures analysis of variance (ANOVA) and the Greenhouse-Geisser procedure for each of the 5 exercises. Reported differences were accepted as statistically significant at $p \leq 0.05$.

Results

Mean EMG data showed that for each exercise tested, the upper and lower portions of the rectus abdominis and the external oblique were recruited (Table 1). There was minimal recruitment of the rectus femoris, an indicator of hip flexor activity, for each exercise tested. Since the mean EMG values for the rectus femoris were consistently below 0.2 V, they were not included in the following tables or figures.

Upper Portion of the Rectus Abdominis

The AB-DOer, Perfect Abs (seated low-resistance band), and the Torso Track (low tension) each elicited significantly less URA activity than a traditional crunch by 85, 72, and 45%, respectively (Table 2 and Figure 1). In contrast, the Perfect Abs performed in the supine position using both the medium- and high-resistance bands exhibited significantly greater URA activity by 58 and 72%, respectively (Table 2 and Figure 1). All other values were not significantly different from a traditional crunch.

Lower Portion of the Rectus Abdominis

The AB-DOer, Perfect Abs (seated low-resistance band), and the Torso Track (low tension) each elicited significantly lower activity from the LRA than a traditional crunch by 78, 63, and 42%, respectively (Table 2 and Figure 2). In contrast, the Perfect Abs performed in the supine position using the high-resistance band exhibited significantly greater LRA activity by 169% (Table 2 and Figure 2). All other values were not significantly different from a traditional crunch.

External Oblique

The AB-DOer was the only exercise device that elicited significantly lower activity in the EO than a traditional crunch. In contrast, the Perfect Abs performed in the supine position using both the medium- and high-resistance bands, the Perfect Abs seated with the high-resistance band, and the Torso Track (high tension) exhibited significantly greater EO activity by 64, 88, 79, and 76%, respectively (Table 2 and Figure 3). All other values were not significantly different from a traditional crunch.

Discussion

This study supports previous findings that there is no significant difference in abdominal muscle recruitment between the Ab Roller Plus and a traditional crunch. Since roller-type devices are designed primarily to facilitate proper form without adding any external resistance, no increase in abdominal muscle activity should be expected when compared with a traditional crunch.

In order for a device to be effective in a seated position, it must provide adequate resistance to counteract the force of gravity eliciting trunk flexion. The principal reason for the significant decrease in abdominal activity when using the AB-DOer is that the vertical support bar does not provide enough resistance to require substantial muscle recruitment. Even with our lighter-weight subjects, flexing their vertebral column enabled the weight of their trunk to bend the vertical support bar. With respect to the AB-DOer, the findings are similar to those reported by Tsai. The minimal abdominal muscle recruitment while performing forward trunk flexion in an upright position has also been confirmed by Bankoff and Furlani and Machado de Sousa and Furlani . In contrast, the Perfect Abs avoided this limitation in the seated position with the medium- and high-resistance bands, because they produced enough load to require comparable abdominal muscle activity as recorded during the crunch.

In order to provide greater overload to the abdominal musculature than a traditional crunch, additional resistance must be provided. In the supine position the Perfect Abs, when using the medium- and high-resistance bands, was significantly more effective than a traditional crunch in recruiting the URA, LRA, and EO. The Torso Track elicited significantly higher EO activity when using the high-tension setting, but no significant difference in URA and LRA activity when using either the low- or high-tension settings.

In summary, all 4 devices elicited abdominal muscle activity when used with proper technique. The Perfect Abs, however, was the only device that not only mimicked a traditional crunch movement, but also provided sufficient external resistance to elicit significantly greater abdominal muscle recruitment than when performing a traditional crunch.

Practical Applications

The data collected in this study verify that portable abdominal devices, when used in a supine position, must provide external resistance to elicit greater abdominal muscle activity than when performing a traditional crunch. Devices used in a seated position provide a viable alternative for performing the crunch motion, particularly for individuals with physical limitations that would prevent them from training in the supine position. These devices, however, must supply adequate external resistance to counteract the force of gravity aiding trunk flexion. A portable abdominal exercise device, which functions with variable resistance, makes it easily accessible and effective for strength and conditioning in the home, gym, on the field, or while traveling. They also enhance the training response because of their ability to provide additional exercise overload.

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Tables

Table 1. Mean electromyography values (mean ? *SE*) for the 11 exercises tested (*N* = 33)

Device/muscle (volts)	Upper rectus abdominis (URA)	Lower rectus abdominis (LRA)	External oblique (EO)
AB-DOer	0.19 ± 0.03*	0.13 ± 0.02*	0.12 ± 0.02*
Torso Track (low tension)	0.72 ± 0.07*	0.34 ± 0.03*	0.34 ± 0.03
Torso Track (high tension)	1.32 ± 0.11	0.68 ± 0.06	**0.58 ± 0.05**
Ab Roller Plus	1.37 ± 0.12	0.58 ± 0.05	0.29 ± 0.03
Perfect Abs (seated low)	0.37 ± 0.04*	0.22 ± 0.03*	0.22 ± 0.02
Perfect Abs (seated medium)	0.87 ± 0.09	0.38 ± 0.04	0.40 ± 0.04
Perfect Abs (seated high)	1.42 ± 0.13	0.58 ± 0.06	**0.59 ± 0.05**
Perfect Abs (floor low)	1.57 ± 0.14	0.70 ± 0.09	0.38 ± 0.04
Perfect Abs (floor medium)	**2.05 ± 0.18**	0.88 ± 0.12	**0.54 ± 0.05**
Perfect Abs (floor high)	**2.23 ± 0.18**	**1.00 ± 0.12**	**0.62 ± 0.06**
Traditional crunch	1.30 ± 0.10	0.59 ± 0.05	0.33 ± 0.04

* Significant decrease in muscle activity relative to a traditional crunch. **Bold** indicates significant increase in muscle activity relative to a traditional crunch; $p < 0.05$.

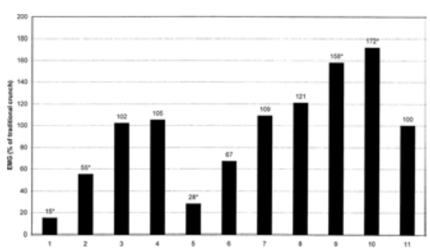
Table 2. Percent difference of mean electromyography (EMG) values relative to the traditional crunch (N = 33).?

Device/muscle (%)	Upper rectus abdom-inis (URA)	Lower rectus abdom-inis (LRA)	External oblique (EO)
AB-DOer	15*	22*	36*
Torso Track (low tension)	55*	58*	103
Torso Track (high tension)	102	115	**176**
Ab Roller Plus	105	98	88
Perfect Abs (seated low)	28*	37*	67
Perfect Abs (seated medium)	67	64	121
Perfect Abs (seated high)	109	98	**179**
Perfect Abs (floor low)	121	119	115
Perfect Abs (floor medium)	**158**	149	**164**
Perfect Abs (floor high)	**172**	**169**	**188**
Traditional crunch	100	100	100

† Since the crunch is the standard to which the other exercises were compared, the EMG values for the URA, LRA, and EO during the crunch were assigned a value of 100%.

* Significant decrease in muscle activity relative to a traditional crunch. **Bold** indicates a significant increase in muscle activity relative to a traditional crunch; $p < 0.05$.

Figures



Click on thumbnail for full-sized image.

Figure 1. Percent difference of mean electromyography (EMG) values for the upper rectus abdominis relative to the traditional crunch. The exercises tested were, numbered above in order, the AB-Doer,

Torso Track (low tension), Torso Track (high tension), Ab Roller Plus, Perfect Abs (seated, low resistance), Perfect Abs (seated, medium resistance), Perfect Abs (seated, high resistance), Perfect Abs (floor, low resistance), Perfect Abs (floor, medium resistance), Perfect Abs (floor, high resistance), and the traditional crunch. The asterisk indicates significant difference in muscle activity relative to a traditional crunch, $p < 0.05$

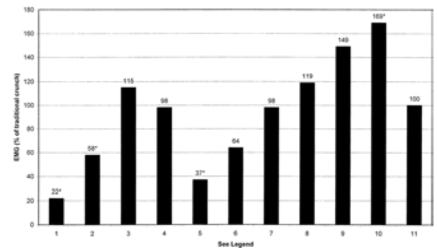


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Figure 2. Percent difference of mean electromyography (EMG) values for the lower rectus abdominis relative to the traditional crunch. The exercises tested were, numbered above in order, the AB-Doer, Torso Track (low tension), Torso Track (high tension), Ab Roller Plus, Perfect Abs (seated, low resistance), Perfect Abs (seated, medium resistance), Perfect Abs (seated, high resistance), Perfect Abs (floor, low resistance), Perfect Abs (floor, medium resistance), Perfect Abs (floor, high resistance), and the traditional crunch. The asterisk indicates significant difference in muscle activity relative to a traditional crunch, $p < 0.05$.

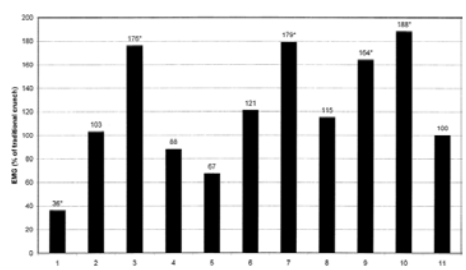

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Figure 3. Percent difference of mean electromyography (EMG) values for the external oblique relative to the traditional crunch. The exercises tested were, numbered above in order, the AB-Doer, Torso Track (low tension), Torso Track (high tension), Ab Roller Plus, Perfect Abs (seated, low resistance), Perfect Abs (seated, medium resistance), Perfect Abs (seated, high resistance), Perfect Abs (floor, low resistance), Perfect Abs (floor, medium resistance), Perfect Abs (floor, high resistance), and the traditional crunch. The asterisk indicates significant difference in muscle activity relative to a traditional crunch, $p < 0.05$.